ISSN 2229-5518

Land Use/Land Cover Change (LULCC) in China, Review of Studies

Terefe Hanchiso Sodango[1*], Jinming Sha[1] and Xiaomei Li[2]

[1] Fujian Normal University, College of Geographical Sciences, Department of Cartography and GIS, Fuzhou, China

[2]Fujian Normal University, College of Environment, Fuzhou, China

* E-mail of the corresponding author: Sodango27912@itc.nl or terefeh@gmail.com

Abstract

China has undergone through unprecedented and dynamic land use/land cover changes (LULCC) since the past many centuries due to the significant transformations caused by natural and human factors. To understand these changes, many studies have been conducted however; there is still considerable uncertainty with regard to LULCC extent, trend and pattern in China. This is mainly due to the complex nature of LULCC processes itself and the spatiotemporal dynamism, data heterogeneities and uncertainties particularly, for pre-satellite era. In this study, more than 72 research articles were evaluated to understand the state of LULCC. The studies used various approaches to investigate LULCC, but the most commonly used approaches were: reconstructing from long-term land surveying historical data, using satellite data, and the combination of both approaches. Among the reviewed research articles, some of them were done in wider spatial and temporal scale and demonstrated deep analysis of LULCC in the country and emerged with sound and holistic findings, whereas some of them tended to focus on specific locality and short time.

Therefore, the main aim of this article is to narratively synthesize and descriptively present the major findings of the studies conducted on LULCC in China. More emphasis was given to pattern and trends, main drivers and negative impacts of LULCC in China and an attempt was also made to include the land monitoring approaches used in some studies.

The review result shows that the LULCC in China has significant spatiotemporal variation in magnitude and trend owing to the heterogeneity of natural resources and population number. The country has experienced a massive expansion of cropland area since AD 800 and a similar scenario had continued for the subsequent thousand years. Then, during 1700 to 2005, forested land shrunk by 22% while cropland increased by 42% and urban areas also expanded. More recently, cropland declined considerably while urban and forest areas expanded. Especially, a serious decline of cropland was observed in the eastern plain, north, and southeast regions of China and a large increase in forested area in the southeast and southwest regions. A substantial number of studies confirmed that the root driver for the LULCCs in the country, particularly before three decades, was population growth. However afterwards, economic growth is mentioned as an important driver with accompanying rapid urbanizations and industrialization processes. But war and natural disasters are not the major drivers since their effect is not significantly changing land use and land cover of the country for several years.

Consequently, this unceasing and unprecedented LULCC in China has resulted in increased habitat and biodiversity loss, desertification, pollution risks, local climate alteration, waste accumulation, and high carbon concentration in the atmosphere as well as other associated problems. Several studies confirmed that there is a substantial and encouraging effort to mitigate the negative impacts of LULCC by the government of China. Hence, since the recent time, forested area has increased however, the afforestation activity was reported to but the effort can be more feasible if it can combine polyculture to improve the biodiversity of the new afforestation activities. Moreover, non-pervious surfaces that are becoming common in cities are causing attractions of local climate and should be closely monitored so as to curb the current urban heat island problem which is noticed in many cities across China. The mining sites, industries, sewage, urban projects, and agrochemical application activities should be monitored to decrease the risk of pollution of soil, air, water and food by pollutants. Moreover, even though China has continuous monitoring of LULCC, extensive and frequent studies that cover the whole country and wider temporal extent is recommended because it can give better insight into the past and the current situations and help to more precisely predict about the future impacts of LULCC in China and subsequent mitigations measures.

Keywords: Land Use Land Cover Change (LULCC), Land Monitoring, Drivers, Pattern, Impact

1. Introduction

Humans have changed the environment with high intensity and speed through land use change during the past centuries [1]–[7]. To understand these phenomena and processes various land monitoring activities as well as land use land cover change (LULCC) studies were performed globally, regionally and locally [1], [2], [4], [6], [8]. Similarly, many studies were done on LULCC of China [4], [9]. Most of studies in LULCC commonly used change detection methods to calculate land cover land use change over space and time [10]. However, in earlier time, finding land cover/use datasets and performing change detection studies was extremely time taking as it was usually performed manually and hence it was difficult to find appropriate datasets that fits to the purpose. Many researchers mentioned the shortage of data for land use land cover studies of earlier eras. For instance, [4], argued that there was a difficulty of finding appropriate and fitting datasets of China for pre-satellite eras (before 1980).

Even though there are discrepancies of datasets and uncertainties due to many factors especially during pre-satellite era, many studies were performed in China using different approaches. For instance, [4], [6], [8] reconstructed historical LCLU datasets by generating from land cover map (represents primary land cover without human disturbance) fractional gridded dataset and a Boolean gridded dataset (represent distributions of cropland, forest, and urban area in each 10 ×10 km grid cell). [4] combined remote sensing based estimations from low resolution sensors (e.g., MODIS and SPOT vegetation) with high-resolution remote sensing data and surveying datasets to analyze LULCC of China in between 1700-2005. Similarly, [8] used an approach to reconstruct spatially explicit changes in global agricultural areas (cropland and pasture) to identify the resulting changes in land cover over the last millennium(between AD 800 and 1700). They used published maps of agricultural areas for the last three centuries and population data for the earlier time as a proxy for agricultural activity and produced output showing the extent of cropland and pasture. Finally, they determined historical land cover change since AD 800 by combining the output of agricultural areas with a map of potential vegetation.
Then after introduction of Remote Sensing technology, most of studies in LULCC and monitoring were using Landsat datasets for global to local mapping applications for many subsequent years. Especially, the launching of Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) datasets became key sources for understanding of information about complex interactions between human activities and land cover change [2]. But the recent advances in data acquisition, data accessibility, and high-performance computing is making it possible to use finer spatial resolution data for global land-cover mapping even more for local land monitoring. Hence, currently more and more LULCC and Land Monitoring studies are shifting their trends from a single general purpose classification to individual application oriented information extractions that focus on local applications such as:

- Human settlements and urbanizations [11]–[17],
- Agricultural lands [8], [18]–[20],
- Wetlands [16], [21]–[25],
- Biodiversity [25]–[32] and
- Quantification of vegetation covers and drought [1], [3], [10], [33]–[35].

Most of the LULCC and monitoring studies done globally as well as in China have commonly used reconstructing from long term land surveying historical data [6], [8], high and low- resolution satellite data [2], [31], [34], [36] and the combination of both approaches [3], [4], [8], [9], [37].
Therefore, the main aim of this study is to review the major findings in LULCC studies in China and present descriptive summary of LULCC in China over long period of time (i.e. AD 800 to present). Moreover, LULCC in China during AD 800 to present was systematically synthesized from various literatures and narratively presented. The spatial extent and pattern of land use land cover change in China, the main drivers for these changes, the ultimate impact and mitigation approaches were briefly discussed in the subsequent sections. Scientific literatures including the previous reviews and related experimental reports that focus on LULCC in China were searched from journal articles and other databases. Mainly the recent review research papers (written in English) and related resources that address the objectives of the study were selected from scientific journals and integrated into bibliographic manager (Zotero) software. All related references were stored in the library and citations were retrieved from the databases. Finally, the main findings of the related publications were synthesized narratively to make descriptive reviews and present a holistic overview of LULCC in China. Finally, summery was provided in descriptive manner and further depicted with conceptual model that states the main drivers of LULCC of the country since AD 800 and its negative impact.

2. LULCC Extent, Pattern, Drivers and Impacts

2.1. Extent of LULCC in China

Even though there are many studies about LUCC in China, only few of them have determined the extent and pattern of LUCC for the whole country over a long period except [8] who has determined LUCC since pre-industrial era for the whole China. Most of remaining studies have addressed the issue from smaller spatial and temporal scale, ranging from watershed to provincial levels. Due to this fact, determining the overall extent and pattern of LUCC for the whole China is extremely difficult. However, cumulative deduction can be made based on these islands of LUCC studies in the country, even though the summary might be not precise and difficult to apply for policy making.
As stated by many studies, China occupies the third-largest land area of the world and supports about 22% of the world's population with only 7% of world's total arable land [6]. Owing to high population number, the country has gone through massive agricultural expansion in earlier times, however high economic growth in recent decades also caused increased land use and land cover change [1], [8], [12], [37], [38]. Even though these significant transformations caused by natural and human factors aforementioned caused the country to undergo through unprecedented use and cover changes over many centuries, the causes for major changes and the change itself was not uniform across time and space [9]. For example, in pre-industrial period, the expansion of agriculture was the dominant process, although little is known about the extent, timing or spatial patterns of these changes[6], [8], [9], [36], [38]–[40]. This can be proved from the expansion of cropland area and agriculture since AD 800 in South Asia associated to rapid expansion of rice from China to the surrounding countries [8]. The expansion of cropland remained for the next thousand years (fig. 2) and rice had a key role in the high expansion rates of crop in the mainland countries in the 19^{th} and

20th century too [8]. Moreover, development of seed agriculture in northern China in the 5th and 6th millennia BC combined to domestication of pigs and tropical vegeculture increased cropland of China to estimated 2.11x105 km^2 by AD 800 [8].

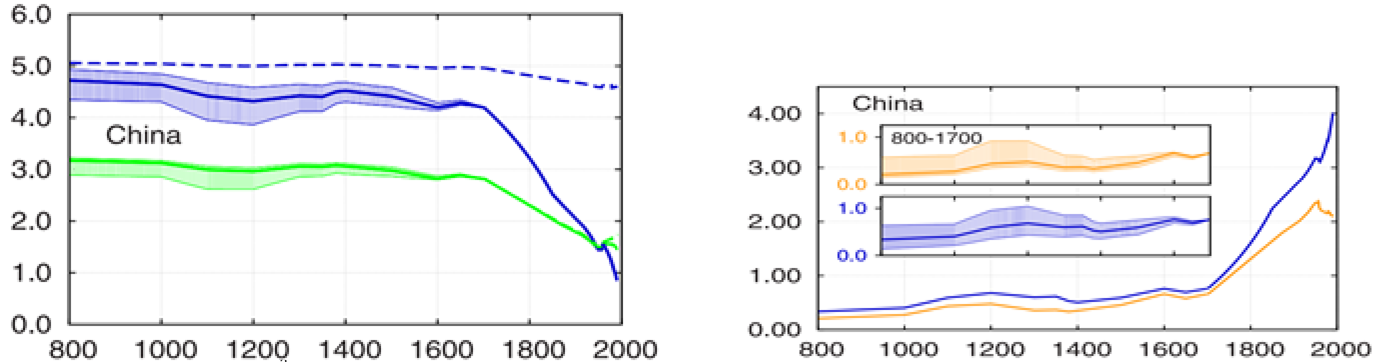

Fig. 1. Left: Total area (in 108 km^2) of natural vegetation: forest (green) and natural grassland, shrub land, and tundra (blue) from AD 800 to 1992. Shaded area indicates the uncertainty range while dashed lines are land cover change due to cropland only. Right: total area (in 108 km^2) crop (orange) and pasture (blue) from AD 800 to 1992. The insets show the time period AD 800 to 1700 at different scale and with shaded area indicating the uncertainty range. Source: (Pongratz et al., 2008)

Moreover, migration from the Yellow River south in the preceding centuries to east had led to a cropland to cover much of the eastern part of the country with increasing focus on rice and the introduction of double cropping. However, two notable events interrupted the strong growth of population and agriculture in the country namely the Mongol invasions in AD 1211, and the fall of the Ming Dynasty in 1644. Thereafter, growth of cropland area was resumed at exceptional pace, and half of China's natural forest cover was transformed to cropland [6], [8], [9], [38] (see fig. 3).

According to [4] rapid population growth remained in the past 300 years (since 1700 to 2005) caused agriculture to expand to forest and grassland areas extraordinarily. Likewise, [3] summarized that over the past 300 years, the area of cropland showed increasing trend in China with growth of 79.46×104 km^2 area from 1661 to the 1980s. Due to cropland expansion forest and grassland decreased by 89.73×104 km^2 and 40.00×104 km^2, respectively. [4] characterized the spatial and temporal patterns of China's LULCC during 1700–2005 by reconstructing historical gridded datasets from high-resolution satellite data and historical survey data.

Overall, the studies confirmed that during 1700 to 2005, forest was shrinking (decreased by 22%) whereas cropland was expanding (increased by 42%) and urban areas such as settlements, factories, quarries, mining, and other built-up land were also expanding with decadal variation in the change (fig. 3).

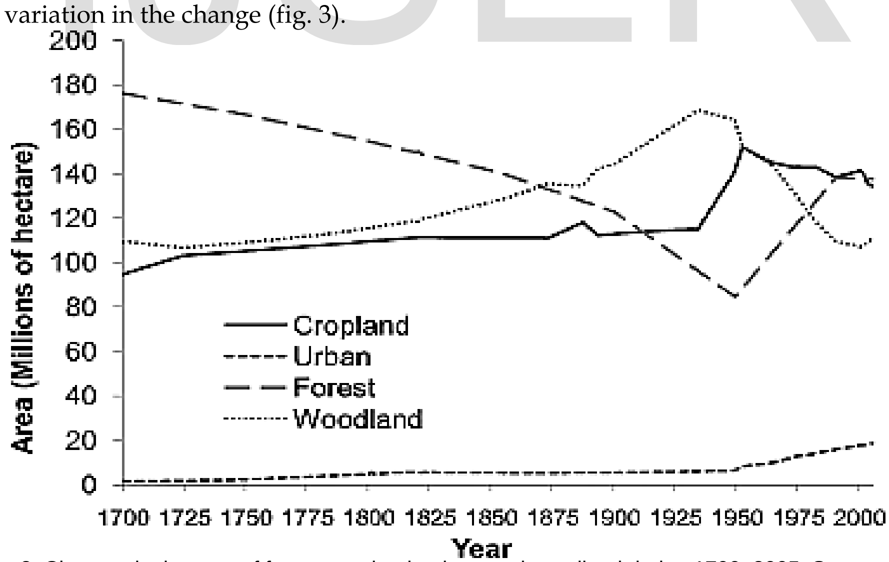

Fig. 2. Changes in the area of forest, cropland, urban, and woodland during 1700–2005, Source: [4]

For instance, during 1980–2005, LULCC was characterized by shrinking cropland, expanding urban and forest areas especially a serious loss of cropland and urban sprawl in the eastern plain, north, and southeast regions of China and a large increase in forested area in the southeast and southwest regions [3], [4], [6], [37], [41]. However, due to changes of Government policies in recent decades, there is tremendous shift in land use so as to balance multiple uses of land resources. These changes in policies have caused changes in cropland and its spatial distribution, as well as an increase in forest plantations [1]–[7]. The substantial fluctuations and high spatial variations of land use and cover change since 1980 indicates that competition among different land uses is becoming intense and the direction of land use change is becoming more sensitive to government policies as well as socio-economic development[42]. Accordingly, ecological recovery programs of the government are a major forces behind the increment of forest land, the reduction of water erosion and protection of wetland covers[43].

2.2. LULCC Pattern in China

LUCC in china had been very dynamic both in the past many centuries due to long history of land use and geographical complexity [38], [44] and recently as a result of fast economic growth, massive rural to urban migration and large scale policy driven ecological restoration [24]. This long trend of LUCC encompasses the conversion among land use types that not only leads to the change of area ratio of land use types but also results in the dynamics of the configuration and proximity land use patterns. Magnitude and trends of LUCC has varied in different places but cumulatively become one of the most important facets of global environmental change[45].

LULCC in China showed significant spatiotemporal variations during different time periods due to heterogeneity in vegetation, soils, and climate and regional imbalance in economic development. For instance, between AD 800 and 1700 there was high transformation of forest land into agriculture and natural grass land into pasture land [8]. During 1700–2005, forests shrunk more dramatically while croplands expanded. Afterwards, settlements (rural and urban) development in China have been in a transition period with the transformation of a traditional agricultural society into a modern industrial and urban society, and hence China has been experiencing an unprecedented and accelerated urban expansion since the 1980s [46]–[52]. Even in between 1990-2000 only the China's urban land has increased by 817 thousand hectares. The change had high spatial and temporal differences, which had been largely driven by demographic change, economic growth, and changes in land-use policies and regulations[32], [33], [53]–[56]. Other studies such as [3], [4], [6], [45] also reported that there was substantial land use changes in early 1980s, from agricultural to urban and industrial purposes but it had significant spatial variations (fig. 4).

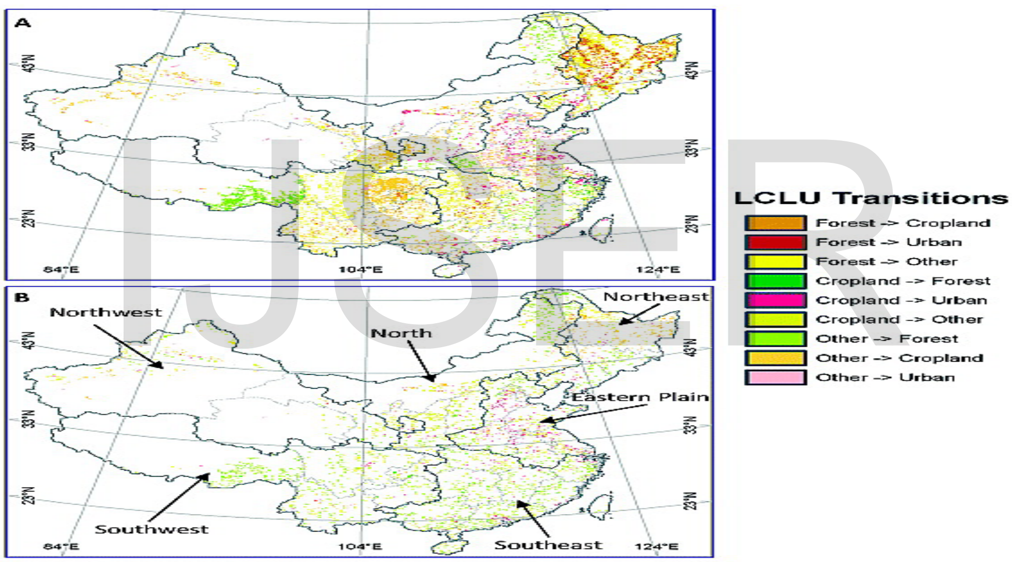

Fig 3. Land cover and land use transitions between (a) 1700 and 2005 and between (b) 1980 and 2005, Source: Source: [4]

[14] stated that Southeast China starting from the Yangtze River Delta to the Pearl River Delta, Bohai See Rim and their neighboring regions witnessed tremendous shift of economic activities with increased construction activities and land expansion in recent years. As a result of urbanization and industrialization that includes settlement and industrial/mining sites, construction and expansion of transportation land were some of the main sources of huge land use change that happened in Shandong Penisula and Tianjin, the coastal Hebei and the coastal Liaoning. [45] stated that cropland change decreased in the south and increased in the north between 1990-2010 years but the total area remained unchanged. Similar to other studies, it confirmed that the built-up area expanded rapidly with high intensity in the east and slowly moving to central and western regions while woodland decreased first, and then increased, but desert area was the opposite, while grassland continued decreasing. As was previously mentioned, the land use and cover pattern of the country was not uniform across time and space, this can be illustrated from land use land cover maps listed below (fig. 5, 6, 7 and 8).

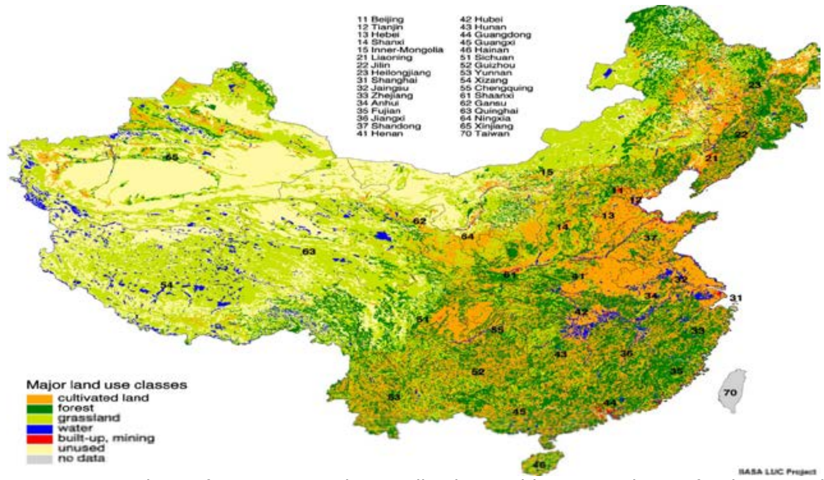

Fig 4. Major Land Use Classes, Sources: Institute of Remote Sensing Applications, Chinese Academy of Sciences: Digital land-cover map of China. Beijing, 1994

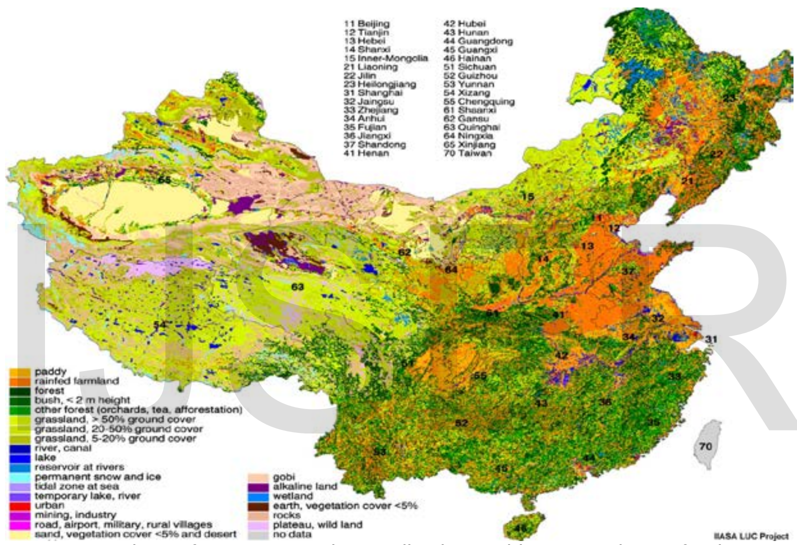

Fig. 5. Detail Land Use Classes Sources: Institute of Remote Sensing Applications, Chinese Academy of Sciences: Digital land-cover map of China. Beijing, 1994

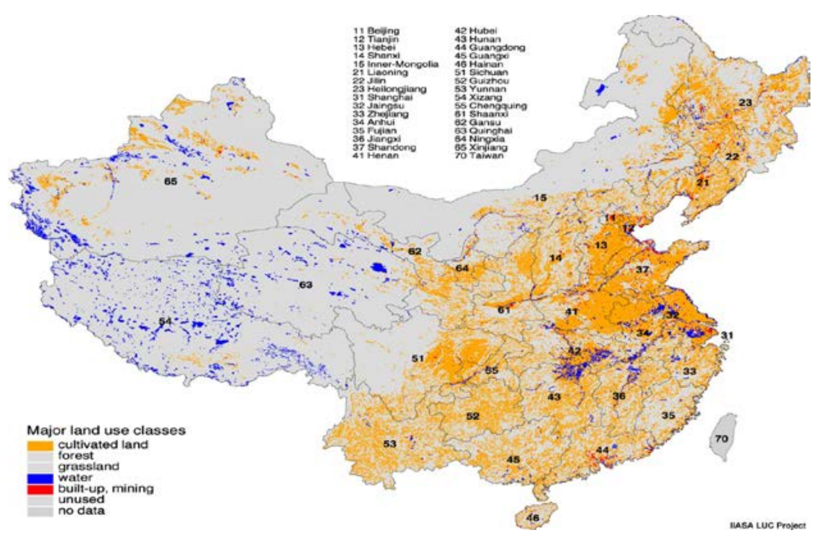

Fig. 6. Cultivated Land, Sources: Institute of Remote Sensing Applications, Chinese Academy of Sciences: Digital land-cover map of China. Beijing, 1994

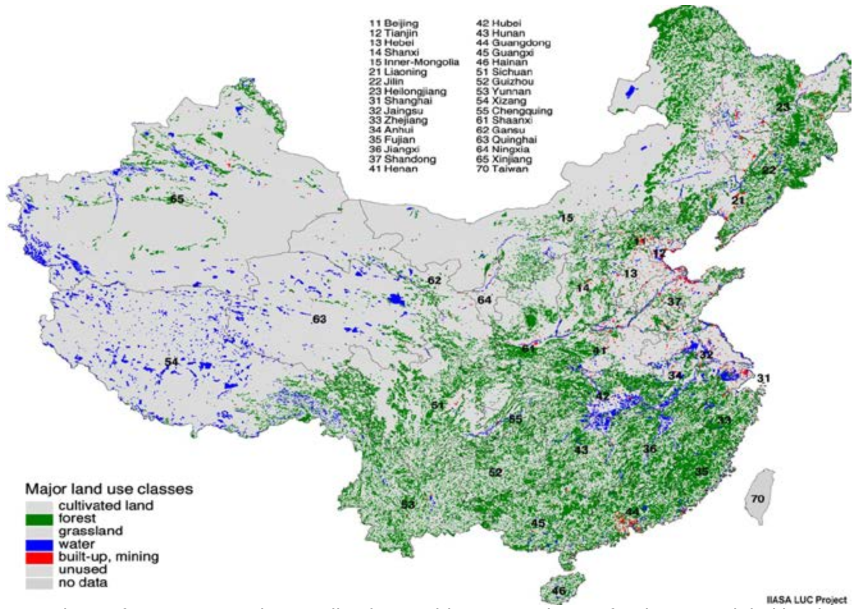

Fig. 7. Forest Land Use, Sources: Institute of Remote Sensing Applications, Chinese Academy of Sciences: Digital land-cover map of China. Beijing, 1994

Indeed, the expansion of cropland in China mainly occurred in the border areas of northeast and southwest, Inner Mongolia and hilly areas of the country in 1990s [3], [4], [6]. This is in agreement with other researches that confirm high expansion of cropland in mentioned areas. In contrary to this, [54] reported that 1.72 million hectares (or 1.3 %) of cultivated land was lost in between 1988 and 1995 including unreported land in the regions of Northwest, East, North, Central and Northeast. As illustrated below (table 1), only one region (i.e. the Plateau) had a net increase of cultivated land from eight economic regions of the country, whereas, the East region had the highest loss of cultivated land during the time. In similar way, the study summarized cumulative land use change in the provinces between 1988 and 1995(fig. 9). Accordingly, Xinjiang had the highest net-increase in cultivated land between 1988 and 1995 whereas Shaanxi had the largest net-decline. This net-change in cultivated land was the result of conversion into grassland and forest land [54].

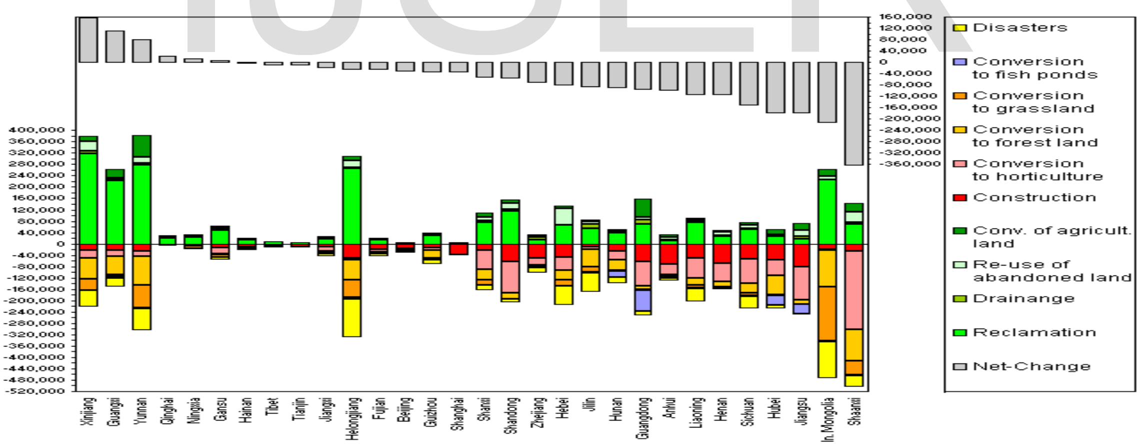

Fig. 8. Increase, Decrease and Net-Change of Cultivated Land in China by Province,1988 - 1995 (in hectares) Source: State Land Administration, Statistical Information on the Land of China in 1995. Beijing, 1996. and equivalent reports for 1988 to 1994.

According to many literatures, there is high uncertainty with the long trends of land-use changes in China, even for the cropland whose record is more reliable than other land use types (Miao et al., 2013). However, according to data obtained from (http://data.worldbank.org/indicator/AG.LND.AGRI.ZS, 2017), there was steady increase in crop land area from 1960 to 1990 but this trend changed since then due to shortage of land area for expansion. Since 1990 to 2014, cropland area remained constant and this trend remained the same in subsequent years (fig. 10). As indicated by many researches, fast economic growth and subsequent urbanization process that was evidenced for the last few decades are the main reasons for decline in expansion of agricultural land in recent years[55]. However, it is extremely difficult to accurately estimate the changes, owing to a lack of reliable datasets.

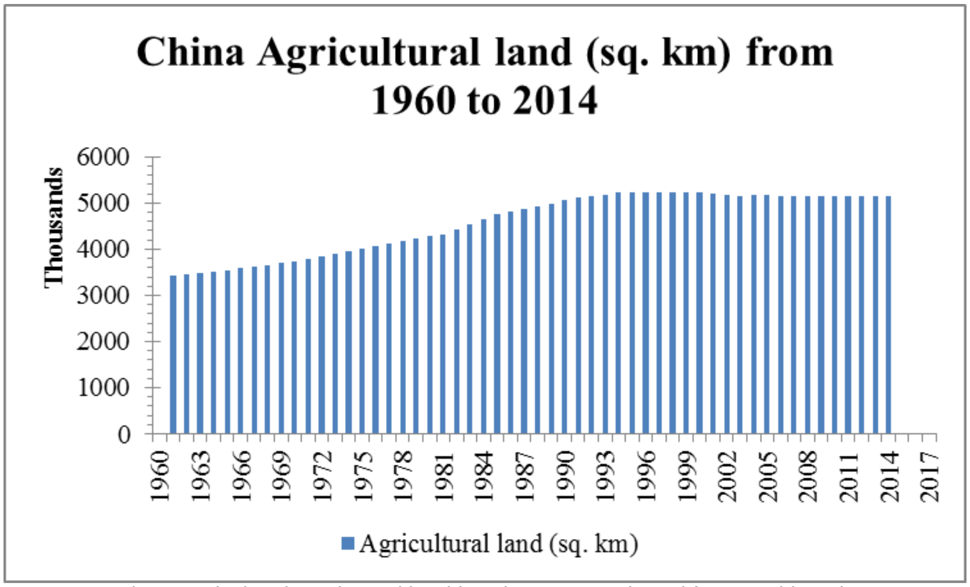

Fig. 9. Agricultural Land Trend in China since 1960, Adopted from World Bank

Table 1. Increase, Decrease and Net-Change of Cultivated Land in China by Region,1988 – 1995, Source: State Land Administration, Statistical Information on the Land of China in 1995. Beijing, 1996. And equivalent reports for 1988 to 1994.

Regions	Cultivated land beginning of 1988	Total increase	Total Decrease	Cultivated Land end 1995	Net Change	
					Hectares	%
North	29,249,933	455,064	795,084	28,909,913	-340,020	-1.16
Northeast	21,566,368	484,666	704,508	21,346,526	-219,842	-1.02
East	14,150,762	143,310	522,634	13,771,437	-379,324	-2.68
Central	12,040,436	127,337	411,108	11,756,666	-283,771	-2.36
South	9,958,018	458,238	469,444	9,946,812	-11,206	-0.11
Southwest	20,781,949	498,101	603,270	20,676,780	-105,169	-0.51
Plateau	975,586	36,094	20,813	990,867	15,281	1.57
Northwest	24,111,838	879,398	1,277,298	23,713,939	-397,900	-1.65
Total China	132,834,891	3,082,208	4,804,159	131,112,940	-1,721,951	-1.3

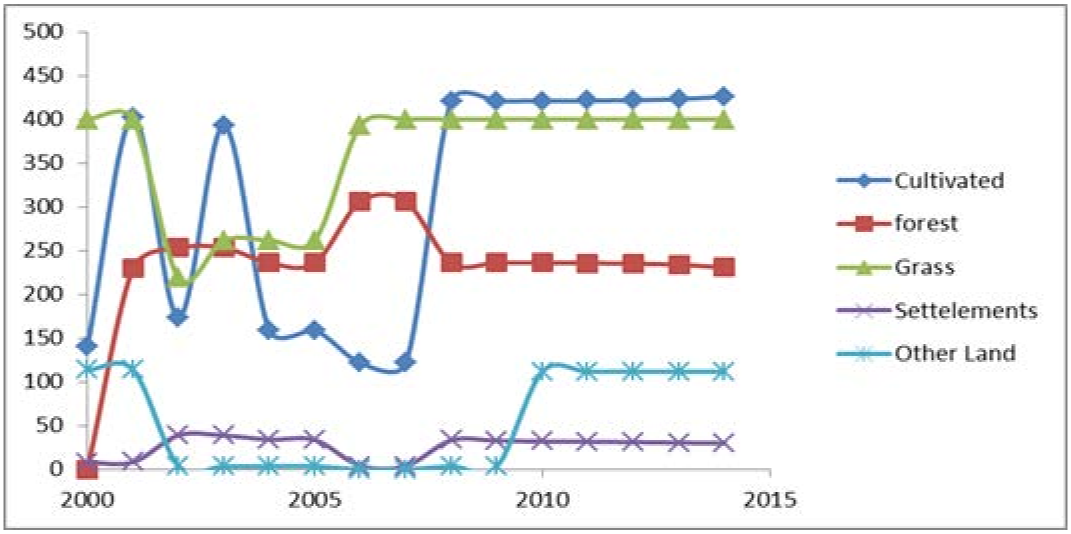

Fig. 10. Statistical land Information on the land use of China by 2000 to 2014 (in 100 hectares), source: Beijing, 2014.

[4] also further stated that there was loss of cropland and urban sprawl in the eastern plain, north, and southeast regions of China and a large increase in forested area in the southeast and southwest regions during 1980– 2005.

This increase in forested area in eastern plains, north and southeast regions was due to the government's increasing concern and commitment for the environment and sustainable use of land. These policies have caused changes in cropland and its spatial distribution, as well as an increase in forested area [46]–[52] mainly in the aforementioned locations.

However according to [4], [55] in the last 30 years, the total area of cropland was nearly constant, although it decreased in southern regions and increased in northern regions. The rapid expansion trend of built-up lands in eastern China was spread gradually out to the central and western regions.

Woodland area was decreased in the former 10 years, and then increased in the latter 10 years. The desert area was increased before 2000 and decreased after 2000. Grassland area showed a continuous decrease in the 20 years. The main anthropogenic driving factors of land use change patterns in the first decade of the 21st century shifted from land development to both land development and environment conservation.

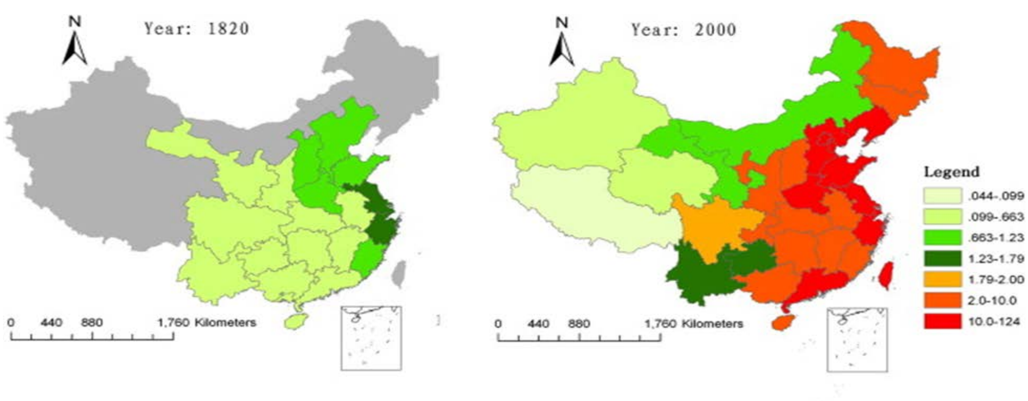

Fig. 11. Spatial distribution of urban land use growth during 1820 and 2000 Source: (Miao et al., 2013)

[55] stated that there was tremendous land use change due to policy shift in China during 2004 to 2008 period. They used county-level data from 2004 and 2008 and examined land use change at the provincial and prefecture city level. They found out that there was direct relationship between spatial pattern of land use change and economic growth of provinces or cities. They further confirmed that there was huge change of land use in the country due to rapid industrialization and urbanization processes and hence the fastest land conversion in China during this time was due to construction uses that consumed 1.26 million hectares.

Even though, the pattern of land use change is highly variable across provinces and prefecture level cities, the general scenario indicates that land expansion for agricultural purpose has declined between 2004 and 2008 whereas land for construction has tremendously increased to 18.83 million mu (table 2).

Table 2 Land use changes in china, 2004–2008, adopted from (Canfei et al., 2012)

Major Land use Categories	2004	2008	Rate of change (%)	Change of Area (million mu)
Agricultural Land	69.11	69.1	– 0.01	– 0.72
Construction Land	3.32	3.45	3.98	18.83
Unused Land	27.57	27.44	– 0.46	– 17.91

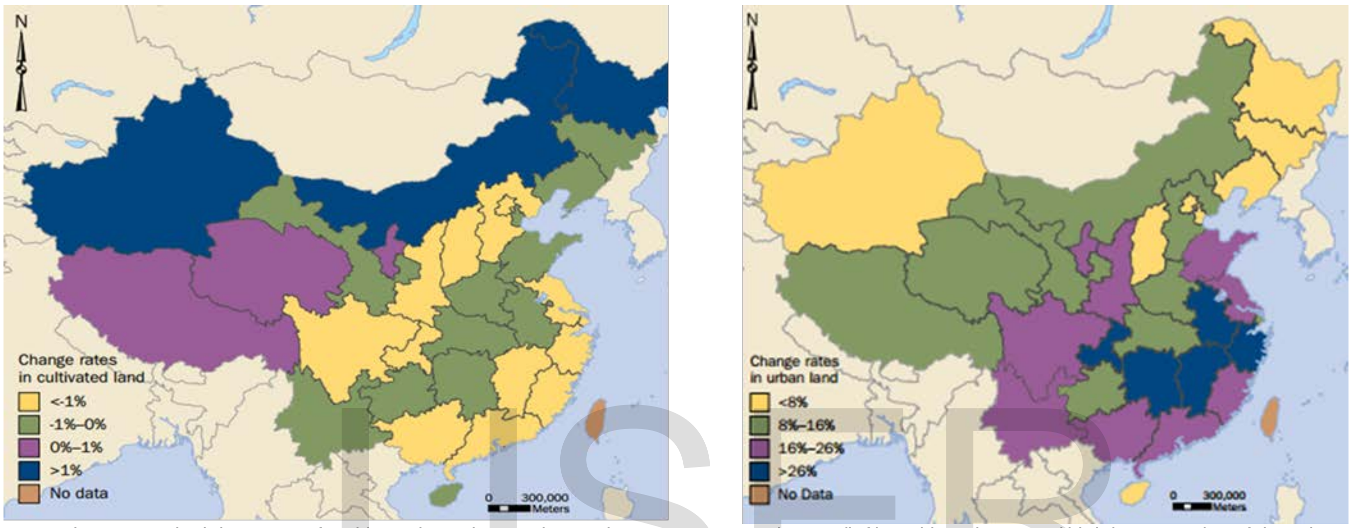

Fig 12. Provincial Pattern of Cultivated Land Use Change between 2004 and 2008 (left) and in Urban Land(right), Source(Canfei et al., 2012)

2.3. Main Drivers of LULCC

LULCC is complex natural process that involves heterogeneous components and interactions between them and hence it is difficult to model and figure out particular drivers for changes. But understanding the main drivers of LULCC is important in formulation of policies and creating awareness to the people. However, different regions have their own drivers for the main changes; for instance, according to[57] regions have different drivers for deforestation.

Many scholars have been interested to identify causes for LULCC. [58] stated that land use is determined by interaction between biophysical factors (soil, climate, topography, etc) and human factors (population, technology, economic conditions, etc) in space and time. While [59] claimed that the cause of LULCC involves two complex systems; the natural ecosystem and the human social system. Additionally, the same study confirmed that the interactions between the two systems determine the success or failure of resource management. Nowadays the most important factor directing modifications and conversions of land cover is the human use, rather than natural change [60]. However the interpretations of the interaction between the human activities and the natural drivers like soil, climate, relief and vegetation are still controversial [61].

However, [60]–[63] classified the driving forces for LULCC into six categories: population; level of affluence; technology; political economy; political structure; and attitudes and values. Of these three categories of driving forces, population produces the most controversy. It is, however, one of the few variables for which worldwide data of reasonable accuracy are available, providing a basis for statistical assessments of its role in various kinds of environmental change. At the regional scale, several studies relate population growth and deforestation in developing countries in the tropics, although their findings and methods have been questioned [62].

According to [3], [4], [6], [9], [26], [37] population growth has been the most important and key driving factor in land cover land use changes in China. China is the third largest country in the world with population number of more than 1.3 billion and comprising 22% of the world population (United Nations Population Division, 2016). The total population of the country has been continuously showing increasing trends (fig. 14).

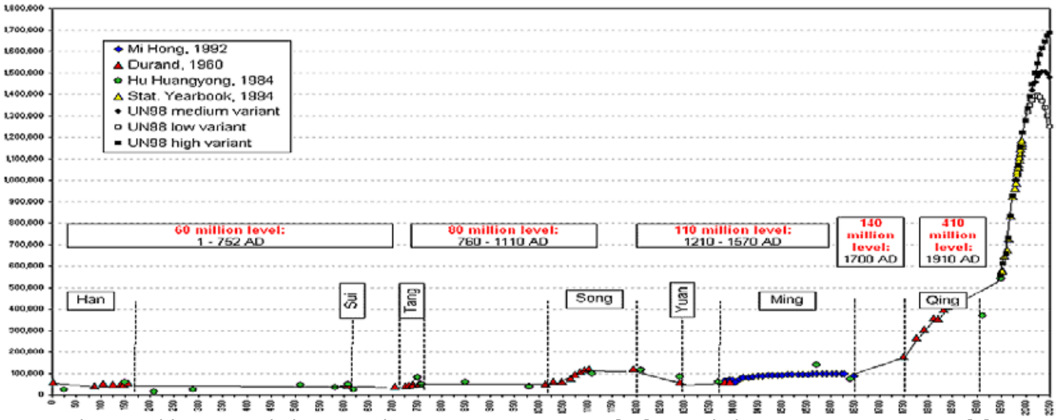

Fig. 13. China's Population Growth, A.D. 0–2050, Source: [54]; Population 1700–2000. Source: [9]

The dynamics was common but not constant over periods of time. From 1724 to 1852, the population maintained fast and stable growth (fig. 14). From 1852 to 1870, there were rapid population fluctuations in negative growth owing to pestilence and famine, the Taiping Rebellion (1851–1864) and the Second Opium War (1856–1860), from 1870 to 1912, a slow, steadily increasing trend occurred; after 1961, the population grew rapidly, but then slowed after 1980 owing to the implementation of the one child policy [54] [9].

Population growth has been referred as root cause for LULCC because population growth has increased the demand for food and associated expansion of agriculture. Specially, in the past periods, high yielding crop varieties and animal breeds, fertilizer and other inputs were not commonly available, and hence to meet high demand for food, expanding cropland was more practiced in China and other parts of the world. But expanding land for increasing production could no more continue as land is limited. Rather cropland expansion faces increasing constraints and food production has increased through increase in agricultural productivity specially this days. In fact, limitations on land expansion already existed as early as around the time of the Jiaqing Emperor (1796–1820), when little fertile land was left for reclamation in the inland regions of China, leading to exploitation of more marginal and remote lands [6], [8], [9], [41].

Historical records revealed the occurrence of serious droughts in 1928–1931 and waterlogging in 1933–1934, which both led to a decrease in cropland areas. Moreover, China's war of resistance against Japan (1937–1945) also caused population fluctuations which were the leading causes of land-use change during those periods. Nevertheless, cropland areas were not significantly reduced during this period, which suggests that disasters and wars were not the main cause of land-use change at that time. But the recent Economic growth has generated enormous demand for land conversion to industrial facilities, transportation infrastructure, residential and recreational uses. The growth of China's economy and market since economic reforms in 1978 have brought very high loss of croplands, most of which were converted to urban areas and transportation routes during 1978–1995[63]. For instance, due to rapid economic development in Shanghai in the last three decades LULCC was characterized by urban expansion and cultivated land reduction. During the period from 1949 to 2010 (past 62 years) cultivated land has significantly decreased with a rate of 26.7 thousand hectares per decade, especially after 1980, cultivated land has decreased rapidly with a rate of 53.5 thousand hectares per decade [13].

[64] reported that as a result of Chinese accelerated economic development in the past 30 years, urbanization developed rapidly, rose from 18% in 1978 to 46.6% in 2009 and is projected to reach 65% by 2030. [14], [55] also stated that urbanization and industrialization are the major drivers of nonagricultural land expansion in China with urbanization rate increased from 40.50 to 45.68 percent between 2004 and 2008. [65] reported that the positive change of urban and forest land were 35.7% and 12.6% respectively during 1980 to 2005 but other land covers have shown a negative trend. Due to large-scale urban sprawl between 1992 and 2015 in the country, urban land was increasing from 1.22 × 104 km2 to 7.29 × 104 km2 mainly by occupying 3.31 × 104 km2 of cropland with an average annual growth rate of 8.10%, almost 2.5 times as rapid as the global average growth rate [66]. These changes were also supported by the following two land cover maps in 1994 and 2010.

[45] also confirmed that in the last two decades, economic driving forces were the main drivers for LULCC in the country but climate change was not the main cause. This implies that economic growth is becoming important driver for LULCC in China whereas war and natural disasters are not the major drivers for LULCC in China. [11], [39], [53] stated that the extensive economic reforms and growth, structural changes and transition from a planned to a market economy and from authoritarian to more decentralized provincial and local government has caused huge change in land use in the last three decades.

2.4. Negative Impacts of LULCC in China

2.4.1. Habitat and Biodiversity Loss

LULCC has important implications for species diversity and composition and hence was cause for species extinction (Ehrlich and Wilson 1991).

China is one of the most biodiversity rich countries in the world having large size and abundance of ecosystems such as: the Hengduan Mountain area that is considered as one of the richest places in the world. According to [67] report, the country has various types of terrestrial ecosystems including 212 types of forest ecosystems, 36 types of bamboo wood ecosystems, 113 types of shrubbery ecosystems, 77 types of meadow ecosystems, and 52 types of desert ecosystems. However, the China's biodiversity has been reported to be threatened and a number of species are on the Red Species Lists [68]. [67] has reported that from about 34,450 higher plant species evaluated, 27 species were categorized as Extinct category (EX), 10 species as Extinct in the Wild Category (EW) and 15 species as Regional Extinct Category (RE). Endangered species among the higher plant species in China totaled 3,767, accounting for 10.9% of the evaluated species. Furthermore, a total of 2,723 species were categorized as Near Threatened (NT) and up to 3,612 species fell into the category of Data Deficient (DD). Up to 10,102 higher plant species required special attention and protection, making up 29.3% of the total evaluated species. This implies that the biodiversity of the country needs

Similarly, [44] reported in only Pearl River Delta area about 25.79% or 1518 km2 of the natural habitat and 41.99% or 760 km2 of the local wetlands were lost during 1992–2012 only. From the general understanding and many reports, the reason for highly threatened biodiversity in China is land cover land use change happened throughout the past years in the form of intensive farming and human settlement in the country. Specially, LULCC across eastern China left very little biodiversity in managed cropland area [28]–[30], [32], [56]. The unique agricultural ecosystems developed over the past millennia have greatly deteriorated in quality, with increasing specialization on a limited number of crops of a single variety with high yield. Recovery of farmland biodiversity is endangered by spread of high-yielding varieties (and increasingly, genetically modified crops), intensive use of agrichemicals, rural industrialization, pollution of freshwater and general infrastructure development are the reasons for the losses. Particularly, due to aforementioned reasons, the eastern and central provinces has been left biodiversity poor.

However, due to Governments intervention to mitigate forest loss, China's forest cover increased from a historical low (in 1949) 85 million hectares to 160 million hectares (in 2002) and then reached 17 percent of the country in 2008. Despite these historically unprecedented increases in forest coverage, the quality continues to decline, in terms of biodiversity. The reason for decline of quality and loss of abundance of biodiversity in afforested areas was attributed to the selected use of monospecies plantation that was commonly practiced in reforestation scheme [28]–[30], [32], [56].

Moreover, there are very encouraging nature reserving activities by the government with a total of 2,729 nature reserves of various types and at different levels had been established nationwide by the end of 2004, with overall coverage of about 146.99 million hectares that accounts for 14.84% of national land area. In-terms of preservation of biodiversity and habitat China has about 10 percent preserved area coverage that comprises over 1,000 small areas. But these biodiversity preservation areas particularly smaller ones are facing enormous human pressures [29], [44].

2.4.2.Desertification

In China, land degradation and desertification is serious problem further exuberated by human activities such as grazing, logging, cropland expansion, and exploitation of underground water, particularly desertification is a major ecological problem in northwestern China [69]. Wu and Ci (1998) reported an increase of sandy desert in the Inner Mongolia since 1950s. Wu (2003) also indicated that the desertification increased fast from the mid-1970s to the late-1980s. [30] also reported that the desert land areas had increased in west Inner Mongolia, but had decreased in Shaanxi, Gansu, and Ningxia. Wind erosion, which can lead to desertification, is a major problem in the arid regions of Northern China, and further reforestation efforts are necessary. However, this degradation problem primarily affects marginal agricultural areas and grasslands in arid regions. Aforementioned and other research findings suggested that human induced land use land cover change is the dominant cause for desertification in China especially in Inner Mongolia. [27] reported the evidence of human induced desert expansion over historical time (dating back to the Han Dynasty), where there was high human-induced desertification of semiarid steppe grassland (Zhuet al., 1988; Sheehy, 1992). [27] mentioned that 94.5 per cent of desertification on sandy steppe or reactivated vegetated dunes was associated with human disturbance. Moreover, over-grazing was a major factor for degrading of grasslands (UNDP/GEF 2005). Overgrazing and long-term overstocking degraded the quality of grasslands in the arid and semi-arid regions of North China, leading to impaired ecosystem functions, substantial decline in forage yield and serious desertification. Furthermore, China's desert ecosystems found in Northwest have been reported as degrading overtime [68]. The total desert area has been increasing due to desertification, and the quality and diversity of deserts is declining.

Therefore, overall the research findings indicated that human disturbance takes the majority of the shares for desertification in China. The recent reforestation schemes in the country improved the vegetation cover or biomass of the forest cover in the country, however, the grasslands that are one of the most widespread ecosystems across arid and semi-arid regions in China, and are of vital importance for human society are under the influence of human activity.

2.4.3.Pollution and Health Effects

According to many literatures, land use and cover changes has created stress on the local, regional and global environment and caused deterioration of air quality. Although, air pollution has been the challenge for megacities across the world, the problem is more serious in some megacities of China. The prime sources for air pollutions in China include industrial emission, vehicle exhaust and urban land use changes [70]. Furthermore, the rising urban heat island problem caused by the increasing impervious surface is also responsible for the decline of air quality in main cities across China. In the same manner, LULCC through urbanization and industrializations caused increasing risk of soil pollution in China through waste disposal and acid deposition derived from urban air pollution and the resulting grain and water pollution [18], [19], [22], [23], [41], [53], [71]–[74]. Many researchers discussed the relationships of LULCC with pollution and human health effects. For instance, [13] stated that urbanization in Shanghai has affected the life of inhabitants with the increased air temperature, hot days and the decrease of relative humidity and wind speed. Particularly the author emphasized the conversion of vegetation into buildings and paved roads as the main reason for increased temperature. [75], stated that 10.18% of Chinese farmland soil was polluted mainly from Cd, Hg, Cu, and Ni. Moreover, the land use and cover change to activities such as: mining, smelting, industry, irrigation by sewage, urban development, and fertilizer application caused pollution of soil by heavy metals and pollute grain, water and air. For example, due to heavy metal pollution in farmland soil, 13.86% of annual grain production was affected in China, that consequently causes human health problems [72], [75].

2.4.4. Climate Change and Variability

Climate change and variability become one of the top issues in recent years at global, regional and local levels. Many studies argued that the LULCC caused by anthropogenic sources is the main factor for climate change. The scenario is the same in China where there is high intensity of LULCC, and consequently there has been a trend of an increasing temperature and variable rainfall in large areas of the country, particularly since 1950 [40]. Mainly conversion of forest land into cropland and built-up areas has caused significant climatic variability. Substantial amount of studies confirmed that conversion of forest to cropland has caused higher surface albedo and climate through associated biophysical changes that modify the water cycle and surface energy balance and also through alterations to the carbon balance [76]. Moreover, it can reduce the evapotranspiration from forest and the resulting precipitation [77]. The same study discussed that the greenness of cropland increased in spring that leads to the cooling and wetting effects and warming and drying effects in the North China Plain during 1982–2006. The change in greenness of cropland caused a daily maximum temperature change that accounted to 47% in spring and 44% in summer. The wetting/drying effects accounted for about 48% of the spatial variations in spring daily minimum humidity change and about 19% in early summer. Therefore, the increased greenness of cropland responds to higher transpiration rate and humidity, less sensible heat flux, and consequently cooling and wetting effects.

Some studies simulated the effect of LULCC on climate and found that the process is very much attached to climate variability. For instance, [78] simulated the climatic effects of cultivated land reclamation and confirmed an increasing temperature and decreasing precipitation during 2030–2040 in Northern Eastern China. Another study in the overgrazing areas of northwestern China simulated that the potential climatic impacts of grassland degradation from 2010 to 2040 will lead to increase of temperature from 0.4–1.2ºC during summer and decreasing in winter by 0.2 º C and decreasing precipitation by 4-20 mm. Similarly, another study also confirmed that LULCC due to urbanization in Shanghai, China is correlated with the increase of air temperature, hot days and the decrease of relative humidity and wind speed [13].

3. Conceptual Framework and Summery

Based on the review of more than 70 research articles, we have developed conceptual framework that summarizes the interaction between components that govern LULCC in China over a long period of time (i.e. since AD 800). The main drivers for LULCC in China can be classified as natural, human and policy factors that are interlinked to each other. These drivers are causing an enormous amount of land use and cover change over a long period of time resulting in negative impacts such as land degradation. Here the positive impacts of land use and cover change is not depicted as the focus of this paper was to point out the extent, pattern, drivers and negative impacts of LULCC in China over long period of time. As stated in the fig. 15 natural factors such as soil type and vegetation cover are one of the reasons for soil erosion in particular and land degradation in general. Particularly, land in the arid and semi-arid areas of the country is very fragile and further influenced by over-exploitation due to overuse caused by overgrazing and over-cultivation. As stated in aforementioned sessions, land degradation is not only due to natural factors but human-induced land degradation take highest share for land degradation in China. Particularly, an increase of population number and associated demand for food, water and shelter is the main reason for accelerated LULCC. An increase in agricultural land (cropland, pasture, orchard and forest land) during early years as well as in recent time is another reason for dramatic LULCC in the country. Even in recent decades where agriculture land is declining, some of agricultural land uses such as orchard and forest land has increased from 2004 to 2008. But since recent rapid economic growth, the socio-economic factors such as fast economic growth, urbanization, industrialization and globalization took their part for fast decline of cropland area and dramatic increase in construction land with high intensity[39]. For instance, in between 2004 and 2008 only the conversion rate of cropland to construction land was very high and it added about 18.83 million mu (1.26 million hectares)[55]. Cultural and traditional factors also cause land degradation to some extent but war and disasters were not the main causes for land degradation in China over a long period of time. However, policy factors such as, land policy and political commitments towards land legislation, administration and protection has played significant role in LULCC of the country. Especially, the recent policy changes in land protection and management has played tremendous role for protection of land from chemical and physical degradation. Moreover, land ownership and transfer policies have their own role in LULCC in the country. Particularly, an amendment to the constitution made in 1988 that enabled the private investors to obtain land use and transfer rights from the

government in certain conditions has caused notable change in private real estate market and associated land use and cover change [79].
Obviously the LULCC over a long period of time has caused negative impacts in the environment and exerted too much pressure on the land causing negative impacts over time. The negative impact the LULCC has in the country is extensive and widespread that needs detailed investigation and studies however the results from many studies can be narrated as land degradation. The ultimate effect of land degradation is negatively impacting quality of life and causing pollution and becoming threat to human health across many parts of the country. Moreover, habitat and biodiversity loss due to LULCC change in the country is overwhelming. Additionally, it is becoming the cause for local and global climate change and variability causing erratic rainfall, drought, flooding and high temperature.

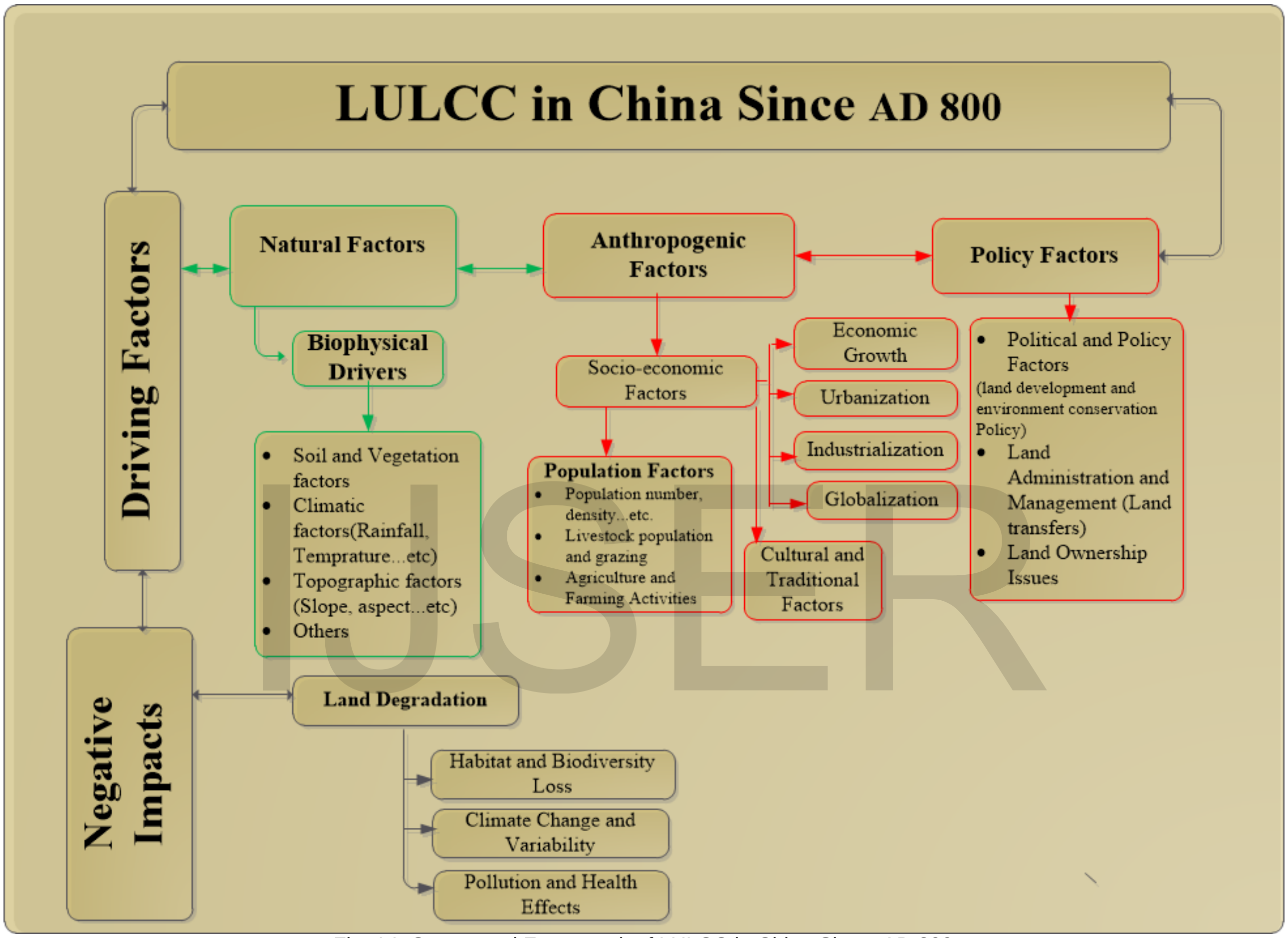

Fig. 14. Conceptual Framework of LULCC in China Since, AD 800

4. Conclusion and Recommendation

China has undergone through unprecedented and dynamic land use and cover changes over many centuries due to the significant transformations caused by natural and human factors. Most of studies done on LULCC in China used reconstructing from long term land surveying historical data, high and low-resolution satellite data and the combination of both approaches.
Since AD 800, China experienced massive expansion of cropland area due to early domestication of agriculture. During 1700 to 2005, forested land shrunk by 22% while cropland (increased by 42%) and urban areas expanded. However, in recent decades cropland shrunk while urban and forest areas expanded. Specially, there was a serious loss of cropland and urban sprawl in the eastern plain, north, and southeast regions of China and a large increase in forested area in the southeast and southwest regions. However, there was clear variation in spatial and temporal pattern of LULCC in the country owing to heterogeneity of natural resources and population number.
The main and root driver for most of earlier LULCC in China was population growth. Particularly, an increase of population number and associated demand for food, water and shelter is the main reason for accelerated LULCC. But since recent rapid economic growth, the socio-economic factors such as fast economic growth, urbanization, industrialization and globalization took their part for fast decline of cropland area and dramatic increase in construction land. Cultural and traditional factors also cause land degradation to some extent but war and disasters were not the main causes for land degradation in China over a long period

of time. However, policy factors such as, land policy and political commitments towards land legislation, administration and protection has played significant role in LULCC of the country. Especially, the recent policy changes in land protection and management has played tremendous role for protection of land from chemical and physical degradation. Moreover, land ownership and transfer policies have their own role in LULCC in the country. Particularly, an amendment to the constitution made in 1988 that enabled the private investors to obtain land use and transfer rights from the government in certain conditions has caused notable change in private real estate market and associated land use and cover change.
Obviously the LULCC over a long period of time has caused negative impacts in the environment and exerted too much pressure on the land causing negative impacts over time. The negative impact the LULCC has in the country is extensive and widespread that needs detailed investigation and studies however the results from many studies can be narrated as land degradation. The ultimate effect of land degradation is negatively impacting quality of life and causing pollution and becoming threat to human health across many parts of the country. Moreover, habitat and biodiversity loss due to LULCC change in the country is overwhelming. Additionally, it is becoming the cause for local and global climate change and variability causing erratic rainfall, drought, flooding and high temperature.
Even though, the LULCC in china has caused habitat and biodiversity loss, desertification and pollution risks, the recent efforts of increasing forested area has significantly increased forest cover and improved natural resources but it is reported to focus on specific species and hence it needs to combine polyculture to improve the biodiversity of forest. Moreover, pervious surfaces should be used in cities to decrease the current urban heat island which is common in cities across China. The mining, industry, sewage, urban projects, and pesticide and fertilizer application activities should be closely monitored to decrease the risk of pollution of soil by heavy metals and associated contamination of grains produced.
From overall researches (Literature written in English) performed on LULCC and land monitoring in the country it is possible to summarize that the country has experienced intense land cover and land use change (LULCC) over a long period of time.
Generally, holistic study that integrates more accurate historical LULCC and methods of monitoring land in China should be performed by multidisciplinary team. This can help to bring better insight to understand the current environmental issues and plan for future risks associated to water quality and quantity loss, desertification, air pollution, soil pollution, biodiversity loss and ecosystems and so on.

5. References

[1] R. S. Defries and J. R. G. Townshend, "Global land cover characterization from satellite data: from research to operational implementation?," Glob. Ecol. Biogeogr., vol. 8, no. 5, pp. 367–379, Sep. 1999.

[2] P. Gong et al., "Finer resolution observation and monitoring of global land cover: first mapping results with Landsat TM and ETM+ data," Int. J. Remote Sens., vol. 34, no. 7, pp. 2607–2654, Apr. 2013.

[3] F. He, M. Li, S. Li, and R. Xiao, "Comparison of changes in land use and land cover in China and the USA over the past 300 years," Springer Sci. Press, vol. 25, no. 9, pp. 1045–1057, 2015.

[4] M. Liu and H. Tian, "China's land cover and land use change from 1700 to 2005: Estimations from high-resolution satellite data and historical archives," Glob. Biogeochem. Cycles, vol. 24, no. 3, p. n/a-n/a, Sep. 2010.

[5] D. Lu, P. Mausel, E. Brondízio, and E. Moran, "Change detection techniques," Int. J. Remote Sens., vol. 25, no. 12, pp. 2365–2401, Jun. 2004.

[6] L. Miao, F. Zhu, Z. Sun, J. C. Moore, and X. Cui, "China's Land-Use Changes during the Past 300 Years: A Historical Perspective," Int. J. Environ. Res. Public. Health, vol. 13, no. 9, p. 847, Sep. 2016.

[7] J. Southworth and C. Gibbes, "Digital Remote Sensing within the Field of Land Change Science: Past, Present and Future Directions," Geogr. Compass, vol. 4, no. 12, pp. 1695–1712, Dec. 2010.

[8] J. Pongratz, C. Reick, T. Raddatz, and M. Claussen, "A reconstruction of global agricultural areas and land cover for the last millennium," Glob. Biogeochem. Cycles, vol. 22, no. 3, p. n/a-n/a, Sep. 2008.

[9] L. Miao et al., "Synthesis of China's land use in the past 300 years," Glob. Planet. Change, vol. 100, pp. 224–233, Jan. 2013.

[10] A. Singh, "Review Article Digital change detection techniques using remotely-sensed data," Int. J. Remote Sens., vol. 10, no. 6, pp. 989–1003, Jun. 1989.

[11] J. Cai, H. Yin, and O. Varis, "Impacts of industrial transition on water use intensity and energy-related carbon intensity in China: A spatio-temporal analysis during 2003–2012," Appl. Energy, vol. 183, pp. 1112–1122, Dec. 2016.

[12] H. Cheng et al., "Overview of trace metals in the urban soil of 31 metropolises in China," Explor. China Environ. Resour., vol. 139, pp. 31–52, Apr. 2014.

[13] L. Cui and J. Shi, "Urbanization and its environmental effects in Shanghai, China," Urban Clim., vol. 2, pp. 1–15, Dec. 2012.

[14] C. He, Z. Huang, and R. Wang, "Land use change and economic growth in urban China: A structural equation analysis," Urban Stud., vol. 51, no. 13, pp. 2880–2898, Dec. 2013.

[15] X. F. Li, Z. B. Chen, H. B. Chen, and Z. Q. Chen, "Spatial Distribution of Soil Nutrients and Their Response to Land Use in Eroded Area of South China," 2011 3rd Int. Conf. Environ. Sci. Inf. Appl. Technol. ESIAT 2011, vol. 10, pp. 14–19, Jan. 2011.

[16] C. Peng, Y. Cai, T. Wang, R. Xiao, and W. Chen, "Regional probabilistic risk assessment of heavy metals in different environmental media and land uses: An urbanization-affected drinking water supply area," Sci. Rep., vol. 6, p. 37084, Nov. 2016.

[17] Y. M. Zheng, T. B. Chen, and J. Z. He, "Multivariate Geostatistical Analysis of Heavy Metals in Topsoils from Beijing, China," vol. 8, no. 1, pp. 51–58, 2008.

[18] H. Cheng, T. Zhou, Q. Li, L. Lu, and C. Lin, "Anthropogenic Chromium Emissions in China from 1990 to 2009," PLOS ONE, vol. 9, no. 2, p. e87753, Feb. 2014.

[19] X. Li, Z. Chen, Z. Chen, and Y. Zhang, "A human health risk assessment of rare earth elements in soil and vegetables from a mining area in Fujian Province, Southeast China," Chemosphere, vol. 93, no. 6, pp. 1240–1246, Oct. 2013.

[20] Y. Ye, X. Wei, F. Li, and X. Fang, "Reconstruction of cropland cover changes in the Shandong Province over the past 300 years," Sci. Rep., vol. 5, p. 13642, Sep. 2015.

[21] L. Chen et al., "An integrated simulation-monitoring framework for nitrogen assessment: A case study in the Baixi watershed, China," 18th Bienn. ISEM Conf. Ecol. Model. Glob. Change Coupled Hum. Nat. Syst., vol. 13, pp. 1076–1090, Jan. 2012.

[22] D. Han, M. J. Currell, and G. Cao, "Deep challenges for China's war on water pollution," Environ. Pollut., vol. 218, pp. 1222–1233, Nov. 2016.

[23] R. Li, M. Chai, and G. Y. Qiu, "Distribution, Fraction, and Ecological Assessment of Heavy Metals in Sediment-Plant System in Mangrove Forest, South China Sea," PLOS ONE, vol. 11, no. 1, p. e0147308, Jan. 2016.

[24] N. Yan et al., "Distribution and assessment of heavy metals in the surface sediment of Yellow River, China," 40th Anniv. RCEES, vol. 39, pp. 45–51, Jan. 2016.

[25] Z. Zhang, S. Liu, and S. Dong, "Ecological Security Assessment of Yuan River Watershed Based on Landscape Pattern and Soil Erosion," Int. Conf. Ecol. Inform. Ecosyst. Conserv. ISEIS 2010, vol. 2, pp. 613–618, 2010.

[26] T. Akiyama and K. Kawamura, "Grassland degradation in China: Methods of monitoring, management and restoration," Grassl. Sci., vol. 53, no. 1, pp. 1–17, Mar. 2007.

[27] Y. Chen and H. Tang, "Desertification in north China: background, anthropogenic impacts and failures in combating it," Land Degrad. Dev., vol. 16, no. 4, pp. 367–376, Jul. 2005.

[28] G. Fenu, D. Cogoni, M. S. Pinna, and G. Bacchetta, "Threatened Sardinian vascular flora: A synthesis of 10 years of monitoring activities," Plant Biosyst. - Int. J. Deal. Asp. Plant Biol., vol. 149, no. 3, pp. 473–482, May 2015.

[29] A. C. Hughes, "Understanding the drivers of Southeast Asian biodiversity loss," Ecosphere, vol. 8, no. 1, p. n/a-n/a, Jan. 2017.

[30] X. Lu et al., "Effects of grazing on ecosystem structure and function of alpine grasslands in Qinghai–Tibetan Plateau: a synthesis," Ecosphere, vol. 8, no. 1, p. e01656–n/a, Jan. 2017.

[31] M. K. Reif and H. J. Theel, "Remote sensing for restoration ecology: Application for restoring degraded, damaged, transformed, or destroyed ecosystems," Integr. Environ. Assess. Manag., p. n/a-n/a, Oct. 2016.

[32] D. S. Schmeller et al., "Towards a global terrestrial species monitoring program," J. Nat. Conserv., vol. 25, pp. 51–57, May 2015.

[33] Å. Kolås, "Degradation Discourse and Green Governmentality in the Xilinguole Grasslands of Inner Mongolia," Dev. Change, vol. 45, no. 2, pp. 308–328, Mar. 2014.

[34] X. Zhao, D. Zhou, and J. Fang, "Satellite-based Studies on Large-Scale Vegetation Changes in ChinaF," J. Integr. Plant Biol., vol. 54, no. 10, pp. 713–728, Oct. 2012.

[35] Y. Zhao et al., "Towards a common validation sample set for global land-cover mapping," Int. J. Remote Sens., vol. 35, no. 13, pp. 4795–4814, Jul. 2014.

[36] L. Yu et al., "Meta-discoveries from a synthesis of satellite-based land-cover mapping research," Int. J. Remote Sens., vol. 35, no. 13, pp. 4573–4588, Jul. 2014.

[37] P. Xiao, H. Li, Y. Yang, L. Wang, and X. Wang, "Land-Use Changes in China During the Past 30 Years," in Land-Use Changes in China, 0 vols., WORLD SCIENTIFIC, 2015, pp. 11–49.

[38] M. Liu and H. Tian, "China's land cover and land use change from 1700 to 2005: Estimations from high-resolution satellite data and historical archives," Glob. Biogeochem. Cycles, vol. 24, no. 3, p. n/a-n/a, Sep. 2010.

[39] E. F. Lambin and P. Meyfroidt, "Global land use change, economic globalization, and the looming land scarcity," Proc. Natl. Acad. Sci., vol. 108, no. 9, pp. 3465–3472, Mar. 2011.

[40] A. Lü, H. Tian, M. Liu, J. Liu, and J. M. Melillo, "Spatial and temporal patterns of carbon emissions from forest fires in China from 1950 to 2000," J. Geophys. Res. Atmospheres, vol. 111, no. D5, p. n/a-n/a, Mar. 2006.

[41] E. Shevliakova et al., "Carbon cycling under 300 years of land use change: Importance of the secondary vegetation sink," Glob. Biogeochem. Cycles, vol. 23, no. 2, p. n/a-n/a, Jun. 2009.

[42] M. Liu and H. Tian, "China's land cover and land use change from 1700 to 2005: Estimations from high-resolution satellite data and historical archives," Glob. Biogeochem. Cycles, vol. 24, no. 3, 2010.

[43] F. Qu, A. Kuyvenhoven, X. Shi, and N. Heerink, "Sustainable natural resource use in rural China: Recent trends and policies," China Econ. Rev., vol. 22, no. 4, pp. 444–460, Dec. 2011.

[44] C. He, Z. Liu, J. Tian, and Q. Ma, "Urban expansion dynamics and natural habitat loss in China: a multiscale landscape perspective," Glob. Change Biol., vol. 20, no. 9, pp. 2886–2902, Sep. 2014.

[45] J. Liu et al., "Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s," J. Geogr. Sci., vol. 24, no. 2, pp. 195–210, 2014.

[46] P. Christensen and G. C. McCord, "Geographic determinants of China's urbanization," Reg. Sci. Urban Econ., vol. 59, no. C, pp. 90–102, 2016.

[47] John Gibson, Chao Li, and Geua Boe-Gibson, "Economic Growth and Expansion of China's Urban Land Area: Evidence from Administrative Data and Night Lights, 1993–2012," Sustainability, vol. 6, no. 11, pp. 7850–7850, 2014.

[48] Joseph DeSalvo and Qing Su, "Another View of Sprawl from Space," University of South Florida, Department of Economics, 2013.

[49] E. Lichtenberg and C. Ding, "Local Officials as Land Developers: Urban Spatial Expansion in China," University of Maryland, Department of Agricultural and Resource Economics, 2008.

[50] Y. Lu, J. Ni, Z. Tao, and L. Yu, "City–industry growth in China," China Econ. Rev., vol. 27, no. C, pp. 135–147, 2013.

[51] Shasha Lu, Xingliang Guan, Chao He, and Jiali Zhang, "Spatio-Temporal Patterns and Policy Implications of Urban Land Expansion in Metropolitan Areas: A Case Study of Wuhan Urban Agglomeration, Central China," Sustainability, vol. 6, no. 8, pp. 4723–4723, 2014.

[52] Yunqian Zhang et al., "Quota Restrictions on Land Use for Decelerating Urban Sprawl of Mega City: A Case Study of Shanghai, China," Sustainability, vol. 8, no. 10, pp. 968–968, 2016.

[53] H. Long, X. Wu, W. Wang, and G. Dong, "Analysis of Urban-Rural Land-Use Change during 1995-2006 and Its Policy Dimensional Driving Forces in Chongqing, China," Sensors, vol. 8, no. 2, pp. 681–699, Feb. 2008.

[54] G. K. Heilig, "Can China Feed Itself? A system for Evaluation of Policy Options." IIASA, 2011.

[55] H. Canfei, H. Zhiji, and W. Weikai, "Land Use Changes and Economic Growth in China," Linc. Inst. Land Policy, no. Land Lines, 2012.

[56] D. Squires, "Biodiversity Conservation in Asia," Asia Pac. Policy Stud., vol. 1, no. 1, pp. 144–159, Jan. 2014.

[57] P. J. Lawrence and T. N. Chase, "Investigating the climate impacts of global land cover change in the community climate system model," Int. J. Climatol., vol. 30, no. 13, pp. 2066–2087, Nov. 2010.

[58] A. Veldkamp and L. O. Fresco, "CLUE: a conceptual model to study the Conversion of Land Use and its Effects," Ecol. Model., vol. 85, no. 2, pp. 253–270, Mar. 1996.
[59] L. Berry, "Land degradation in China: Its extent and impact," United Nations, 2003.
[60] B. L. Turner, D. Skole, S. Sanderson, G. Fischer, L. Fresco, and R. Leemans, "Land-use and land-cover change: science/research plan," in Unknown Host Publication Title, International Geosphere-Biosphere Programme, Stockholm; Report, 35, 1995.
[61] W. B. Meyer and I. BL Turner, "Changes in land use and land cover: a global perspective," 1994.
[62] R. Walker, "Theorizing Land-Cover and Land-Use Change: The Case of Tropical Deforestation," Int. Reg. Sci. Rev., vol. 27, no. 3, pp. 247–270, Jul. 2004.
[63] J. Chen, "Rapid urbanization in China: A real challenge to soil protection and food security," CATENA, vol. 69, no. 1, pp. 1–15, Jan. 2007.
[64] Q. Xu, Q. Jiang, K. Cao, X. Li, and X. Deng, "Scenario-Based Analysis on the Structural Change of Land Uses in China," Adv. Meteorol., vol. 2013, p. e919013, Nov. 2013.
[65] M. Liu and H. Tian, "China's land cover and land use change from 1700 to 2005: Estimations from high-resolution satellite data and historical archives," Glob. Biogeochem. Cycles, vol. 24, no. 3, p. GB3003, Sep. 2010.
[66] M. Xu, C. He, Z. Liu, and Y. Dou, "How Did Urban Land Expand in China between 1992 and 2015? A Multi-Scale Landscape Analysis," PLoS ONE, vol. 11, no. 5, May 2016.
[67] Minister of Environmental Protection and The People's Republic of China, "The 2014 Report on the State of the Environment in Chinais hereby announced in accordance with the Environmental Protection Law of the People's Republic of China.," Minister of Environmental Protection The People's Republic of China, 2015.
[68] C. Klok and Z. Tiehan, "Biodiversity and its Conservation in China; Authorities, Mandates and Conventions.," Wageningen, Netherlands, Wageningen, Netherlands, Alterra-rapport 1733, 2008.
[69] Q. Feng, H. Ma, X. Jiang, X. Wang, and S. Cao, "What Has Caused Desertification in China?," Sci. Rep., vol. 5, p. 15998, Nov. 2015.
[70] G. Xu et al., "Examining the Impacts of Land Use on Air Quality from a Spatio-Temporal Perspective in Wuhan, China," Atmosphere, vol. 7, no. 5, 2016.
[71] Q. Mu, M. Zhao, S. W. Running, M. Liu, and H. Tian, "Contribution of increasing CO2 and climate change to the carbon cycle in China's ecosystems," J. Geophys. Res. Biogeosciences, vol. 113, no. G1, p. n/a-n/a, Mar. 2008.
[72] Z. Huang, X.-D. Pan, P.-G. Wu, J.-L. Han, and Q. Chen, "Health Risk Assessment of Heavy Metals in Rice to the Population in Zhejiang, China," PLOS ONE, vol. 8, no. 9, p. e75007, Sep. 2013.
[73] C. Shiuh-Shen, "Chinese eco-cities: A perspective of land-speculation-oriented local entrepreneurialism," China Inf., vol. 27, no. 2, pp. 173–196, Jul. 2013.
[74] T. Ye, Y. Gong, and X. Meng, "Experimental Study on Chromium Contaminated Sites by Geophysical Methods," Second Int. Conf. Min. Eng. Metall. Technol. MEMT 2011, vol. 2, pp. 223–228, Jan. 2011.
[75] X. Zhang, T. Zhong, L. Liu, and X. Ouyang, "Impact of Soil Heavy Metal Pollution on Food Safety in China," PLOS ONE, vol. 10, no. 8, p. e0135182, Aug. 2015.
[76] Y. Li et al., "Potential and Actual impacts of deforestation and afforestation on land surface temperature," J. Geophys. Res. Atmospheres, vol. 121, no. 24, p. 14,372-14,386, Dec. 2016.
[77] J. Liu et al., "The climatic impacts of land use and land cover change compared among countries," J. Geogr. Sci., vol. 26, no. 7, pp. 889–903, 2016.
[78] G. Xuejie, L. Yong, L. Wantao, Z. Zongci, and F. Giorgi, "Simulation of effects of land use change on climate in China by a regional climate model," Adv. Atmospheric Sci., vol. 20, no. 4, pp. 583–592, Jul. 2003.
[79] Z. Yuan, "Land Use Rights in China," Cornell Real Estate Rev., vol. 3, no. Cornell Real Estate Review, pp. 73–78, 2004.