Review

How Large-Scale Anthropogenic Activities Influence Vegetation Cover Change in China? A Review

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Abstract: Vegetation cover plays a key role in terrestrial ecosystem; therefore, it is important for researchers to investigate the variation and influencing factors of vegetation cover. China has experienced a large-scale vegetation cover change in recent years. We summarized the literature of vegetation cover change and revealed how large-scale anthropogenic activities influence vegetation cover change in China. Afforestation and intensification of cropland played a key role in large-scale greening. Urbanization showed a “U” shape to influence vegetation cover change. Mining and reclamation, land abandonment and land consolidation, and regional natural protection all had a unique influence on the change of vegetation cover. Indeed, the large-scale vegetation cover change was caused by interaction of anthropogenic factors and part human-driven climate change. Anthropogenic factors influenced climate change to indirectly alter the condition of plant growth. Interaction between climate change and human activities influence on vegetation cover still needs to be further investigated in the future.

Keywords: anthropogenic activities; vegetation cover; greening; China

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1. Introduction

Vegetation cover plays a vital role in terrestrial ecosystems, which are related to climate change, carbon storage, soil erosion, and biodiversity. Therefore, it is important for researchers and government to monitor the vegetation cover change and investigate the influencing factors of vegetation cover change.

With the rapid development of society, several anthropogenic activities have faced trade-off between development and environment. More and more researchers revealed the contradictions and investigated trade-offs to achieve “win-win” and sustainable development. Economic development needs the promotion of different industries, such as urban sprawl, light industry, heavy industry, and mining industry. High-quality needs of life also drive the economic prosperity in cities and villages. In fact, land is the key point of industrial development and basic needs to achieve workshop construction and life infrastructure. For example, the process of open-pit mining strips topsoil, which destroys local environment and vegetation cover. Furthermore, anthropogenic-development driven rapid urbanization alters original ecosystems, and urban expansion was the cause of vegetation cover decrease and environmental degradation that has been observed in many cities all around world [1–3]. In summary, it seems that anthropogenic activities lead an irreversible process in human-driven development. Nevertheless, large-scale anthropogenic activities actually paid more attention to global environment, including vegetation cover, which

has accelerated to alter part of terrestrial ecological environment in a positive direction. Governments have implemented a series of ecological policies to promote the vegetation cover increase. Significant greening has been observed globally in recent years, especially in China and India, which have made a great contribution [4,5]. In fact, Chinese greening was mainly driven by anthropogenic factors, such as afforestation and agricultural intensification. Especially, the Loess Plateau was studied, which had significant increase in vegetation cover [6].

Though previous reviews sorted the literature of vegetation cover change and related influencing factors, the review about anthropogenic factors that directly or indirectly affected the total vegetation cover change was still lacking in recent research. It is necessary and beneficial to summarize what large-scale anthropogenic factors were concluded to influence the vegetation cover change and how to affect the positive or negative changes of vegetation cover. Therefore, the objective of our review was to sort related literature and, thus, to investigate how large-scale anthropogenic factors influence vegetation cover. Our review would give deeper and clearer understanding of the disturbance and effect of anthropogenic factors on vegetation cover, and further our comprehension of how human-driven activities have impact on the environment (Figure 1).

Figure 1. Workflow of the review.

2. General Changes of Vegetation Cover

NDVI datasets were used to investigate changes in vegetation cover in our study based on MODIS and SPOT (Figures 2 and 3). Changes in vegetation cover showed large-scale greening in China, despite parts of some regions displaying degradation in vegetation cover. The Loess Plateau was previously one of the most well-known fragile areas in the world. The region experienced an obvious greening by afforestation and planting grass. Meanwhile, urbanization displayed a significant degradation and coastal areas demonstrated obvious deforestation.

Figure 2. Changes in vegetation cover from 2000 to 2020 based on MODIS.

Figure 3. Changes in vegetation cover from 2000 to 2018 based on SPOT.

3. Influence of Anthropogenic Activities

3.1. Afforestation

Deforestation has seriously affected the ecological environment, which has led to soil erosion and changes of local climate. Indeed, without the blocking effect of vegetation, surface runoff is dramatically increased. Furthermore, the runoff partly depends on the gradient and elevation of deforestation areas. In recent years, the Chinese government has gradually had to pay attention to the ecological environment and input money to increase vegetation cover, improve quality of the environment and control the desertification. Indeed, afforestation-induced greening was observed in China in recent years based on various remote sensing datasets [4,7,8]. The famous and ambitious projects were “Grain for Green” projects and Three North shelterbelt projects, which were considered the main driven factors in large-scale greening [9]. Indeed, the series of ecological engineering increased the afforestation areas that showed strong correlation with vegetation cover [10,11]. Afforestation mainly distributed in semiarid regions and the main ecological projects, i.e., cropland retirement and revegetation, aimed to achieve improved vegetation cover [12,13]. Furthermore, afforestation focused more on the ecologically fragile regions that were induced by heterogeneous topography, climatic conditions, different types of land, and different local environments to promote the improvement of vegetation cover [6]. “Grain for Green” projects encouraged farmers to prevent cultivation in areas of more than 25°, which could lead to serious soil erosion. The Three North shelterbelt projects aimed to control the desertification that was induced by serious climate conditions and the condition of the land. Several studies evidenced that afforestation could effectively improve vegetation cover to achieve ecological restoration in semiarid regions [14]. In fact, afforestation-induced improvement of vegetation cover altered the self-regulating ability of ecosystems to combat climate disturbance, which may reduce the risks of desertification [15]. It played a key role in controlling desertification through promoted reliability of soil surfaces and influenced ecological communities in semiarid deserts [16]. Meanwhile, the vegetation cover increased, leading to improved water-use efficiency, which could, in turn, achieve more efficient use of water in the case of limited water resources [17].

Afforestation-induced greening had an influence on hydrology in China [18]. Changed vegetation cover would influence local climate change, which could influence hydrology. Indeed, large-scale afforestation partly relieved global warming by decreasing local surface air temperature [19]. Afforestation brought a few benefits to the local environment. Nevertheless, anthropogenic planting of trees and grass also needed scientific planning. Related studies showed that grassland and shrubland should be considered in “Grain for Green” projects instead of unitary afforestation to achieve better effects in terms of soil and water conservation [20], because artificial forest consumes more water than natural forest, which aggravates the decline of underground water and the increase in atmospheric water demand [21–23]. Furthermore, related studies also reported inappropriate tree species probably leading to environmental degradation [24]. Optimal combinations of multiple species should all be considered in afforestation, based on soil types and topography [25]. Therefore, it was necessary to pay more attention to suitability and systematicity of afforestation for achieving the sustainable improvement of vegetation cover.

3.2. Urbanization

Urbanization is the process of anthropogenic development that induces the land use cover change. Urban areas and rural settlements had thorough difference from natural environments due to anthropogenic transformation. In fact, cropland, grassland, and idle land were the main land use types in the rural–urban fringe. Urbanization occupied the original ecosystem and destroyed the vegetation, which showed that the process of urbanization had seriously negative effects on vegetation cover in the regions of development [26–28]. Nevertheless, several studies’ results showed that many cities were experiencing periods of revegetation, and the variation of vegetation cover demonstrated an obvious “U” shape, i.e., restarting accelerated greening by an-

thropogenic vegetation gain after urban expansion [29–31]. Megacity Shanghai revealed vegetation cover increase and decrease in downtown and rural–urban fringe, respectively [32]. The enhancement of vegetation growth compensated the loss of vegetation productivity due to urban expansion [33]. Urban environmental management was the main factor that contributed to the improvement of urban green space [34]. Indeed, central and local government implemented a series of policies such as “Ordinance of Urban Greening” (http://www.gov.cn/gongbao/content/2017/content_5219138.htm (accessed on 3 January 2021)) to require a rate of vegetation cover that depended on the construction of urban parks and urban green space, which compensate the large-scale loss of vegetation cover in the early stage of urban development. The effects of urbanization on vegetation cover are shown in Figure 4.

Figure 4. The effects of both urbanization and urban greening.

3.3. Mining and Land Reclamation

The economic development partly depended on the mining industry. Mining was mainly divided into two parts based on mining methods, i.e., surface mining and underground mining, which had seriously negative effects on local environment. Firstly, the process of mining and related industries alters original ecological environment and decreases vegetation cover. Secondly, the mining process produced a large number of by-products, such as gangue, which resulted in soil pollution, land occupation, and land damage. In particular, surface mining stripped and dumped the topsoil, which dramatically altered and destroyed growth conditions of vegetation [35]. The large pits would be formed due to excavation of heavy machinery, which meant that local microtopography would be altered thoroughly. Meanwhile, underground mining could cause the displacement and subsidence of the mine surface. The cropland around some mining regions would transfer surface water due to surface subsidence, which could cause irreversible damage to the land and its crops.

The Chinese government implemented “Ordinance on land reclamation” in 2011, which meant the state could require to restore the mining land by legal means. It aimed to protect damaged land and restore original vegetation cover by anthropogenic assistance. Land reclamation mainly promoted improvement of vegetation cover in dumps that improved soil’s physical properties [36,37]. Meanwhile, the soil properties were improved by land rehabilitation in areas of underground mining, which could be more beneficial to restoration and growth of vegetation [38]. The systemic methods and processes of land reclamation have been revealed and applied in many studies. Systemic techniques,

i.e., geomorphological reshaping, soil reconstruction, vegetation restoration, landscape reconstruction, and biodiversity reconstruction and protection were proposed to achieve scientific land reclamation (<http://jlp.mnr.gov.cn/global/reward!readResult.do?resultId=2c9e80855e5ddb6c015e5fc573b9033d> (accessed on 3 January 2021)) [39]. Positive anthropogenic activities should take mine types, local environment, and intensity of disturbance into consideration before vegetation restoration [40]. The process and reclamation of surface mining and underground mining are displayed in Figures 5 and 6, respectively.

Figure 5. The process and reclamation of surface mining [39].

Figure 6. The process and reclamation of underground mining.

3.4. Land Abandonment and Land Consolidation

Due to migration of rural population to cities, the abandonment of cropland was a common situation of land use change in some regions of China, which led to land degradation and vegetation cover decrease without large-area crops [41]. Some farmers did not transfer their contracted land to other farmers, and also hindered large-scale mechanization of agriculture. Off-farm employment that brought additional revenue had a robust influence on land transfer [42,43], because stable employment contributed to an increased willingness of the farmer to live in the city and to transfer their cropland. Overall, land abandonment not only influenced the planting of crops in growth seasons but also lost opportunities of mechanical processes such as applying fertilizer, scientific irrigation and precise mechanical seeding, which resulted in no significant changes or even dramatic decrease in vegetation cover. Therefore, the Chinese government separated rural land ownership rights, contract rights, and management rights, which promoted the enthusiasm of land circulations (management rights). In fact, land circulations could not only alter the situation of land abandonment but also implement large-scale mechanization of planting for multiple merged parcels, which was conducive to the increase in crop production and vegetation cover. Government policy affected the choice of farmers and, thus, the vegetation cover in rural regions.

Land consolidation increased the efficiency of land use in promoting the vegetation cover [44,45]. In fact, land consolidation helped to improve the suitability of land use and thus increase agricultural production [46]. The projects of land consolidation took engineering measures to merge fragmentary cropland, which was beneficial to the agricultural mechanization. Most of the land consolidation projects had significant effectiveness on vegetation cover increase in China [47].

3.5. Regional Natural Protection

National Natural Protection programs were implemented to protect biodiversity and natural vegetation. Nevertheless, National Natural Protection programs still showed uneven distribution, which limited the efficiency of protection for vegetation [48]. Especially, the karst districts, Junggar Basin, Tianshan Mountains, West Kunlun Mountains, and Loess Plateau should be the subject of more consideration for vegetation protection in China [49]. Regional natural protection aims to protect natural environment and keep biodiversity. In fact, ecological ecosystems regulate material circulation and energy flow, which could achieve a more stable increase in vegetation cover without negative anthropogenic disturbance. National Natural Protection programs were reported to play a key role in maintaining the stability of ecosystems, through controlling the density of population around natural protection regions [50].

3.6. Fallow and Intensification of Cropland

With rapid urbanization and economic development, more and more rural labor transferred into cities and families gradually migrated to urban regions. In fact, previous research concluded that labor force was the most important factor to influence land fallow [51]. The Chinese government expanded trials of fallow systems and crop rotation that aimed to improve production of crops and achieve sustainable development. Though vegetation cover dramatically decreased in the periods of land fallow compared with other years, the production of crops could be increased on the premise that other variables were not significantly adverse or unchanged. In this regard, it was vital to pursue sustainable development of cropland for China's overall vegetation cover, which could advance the "win-win" between sustainability and food security, thus achieving long-term greening instead of temporarily positive change.

Overall, the investment in all aspects of cropland was increasing due to dual drivers of government policy support and planting conditions optimization. The demand of crops continued to increase with the improvement of quality of life and the increase in population. The famous agricultural areas were contributed to in service of China. Cropland showed the highest increase in rate of vegetation cover compared with other land use types in 400 mm annual precipitation fluctuation zones [52]. The new agricultural techniques interfered with traditional methods, which rapidly improved production of crops, thus promoting improvement of total vegetation cover. In general, the improvement of vegetation cover in cropland was driven by meteorological factors and anthropogenic factors (Figure 7). Meanwhile, parts of climate factors were affected by human activities, such as carbon emission. Intensive human input and management contributed to the increase in vegetation cover in croplands.

3.7. Fire and Prevention

Fire dramatically influences local environment and leads to sharp decrease vegetation cover [53]. Due to extremely high temperature and dry environment, wildfire would have a higher probability of occurrence. Nevertheless, the frequency, effects, and severity of fire are decided by different vegetation types and various ecosystems [54,55]. Interaction between fire and vegetation forms a heterogeneous spatial pattern of vegetation and topography, which influences the effects of fire on vegetation [56]. Frequent fire even radically alters the types of vegetation in some vegetation types [57]. From the perspective of remote sensing, the values of vegetation cover would be observed to dramatically and negatively

change. In fact, not only natural factors but also anthropogenic accidental disturbance causes occurrence of forest fire and, thus, influence on vegetation cover. For example, cigarettes and campfires could cause fire in forest. The high rate of cropland contributed suppression of fire that partly decreased the loss of vegetation due to wildfire [58].

Figure 7. The influencing factors of cropland.

4. Influence of Government Policies

Government policies play a key role in vegetation cover increase. In fact, the Chinese government implemented a series of ecological policies to promote improvement of the ecological environment. Government policies that aimed to improve ecological environment are displayed in Figure 8 and Table 1. The policies referred to various aspects including afforestation, protection, plating grass, and reclamation.

Figure 8. A few of government policies about ecological engineering. (Referred from [59] and <https://www.gov.cn/> (accessed on 3 January 2021)).

Table 1. Effects of ecological policies and activities implemented by government on vegetation cover.

Main Observed Change	Year	Regions	Primary Factors
Increasing trends in the annual NDVI change [60]	1982–2015	China	-
Vegetation increasing after 1999 [6]	1982–2015	China's Loess Plateau	Human activities
Mean NDVI increased [9]	2000–2016	China's Loess Plateau	"Grain for Green Project"
NDVI significantly and slightly increased [61]	1999–2015	China's Loess Plateau	"Grain for Green Project"
Vegetation degradation in China farm zone [53]	1982–2015	Amur-Heilongjiang River Basin	Human activities
A greening trend [62]	2000–2015	Pastoral ecotone of northern China	Ecological engineering
Vegetation increased significantly [63]	2000–2015	Rocky desertification area of China	Ecological engineering
Vegetation area and NDVI increased significantly [64]	1990–2015	China	Ecological restoration projects
Vegetation increased in most of areas [65]	2000–2013	Shanxi Province of China	Ecological policies
Vegetation cover improved steadily [66]	2000–2016	Wuqi County of China	"Grain for Green Project"
Vegetation cover increased [67]	2000–2016	Pearl River Delta of China	Human activities (such as afforestation)
Most of region revealed increasing trends [68]	2000–2015	Sanjiangyuan region of China	Ecological engineering
Greening [4]	2000–2017	China	Afforestation, intensification of cropland
Significant vegetation greening [69]	2000–2016	Southwest China	Karst ecological restoration engineering

5. Interaction of Anthropogenic and Climatic Change

5.1. Carbon Dioxide Emissions and Global Warming

Research concluded that China and India are leaders in terms of global greening [4]. Meanwhile, the related research reported that carbon dioxide was the main driver (70%) contributing to global greening [70]. In fact, carbon dioxide concentration increase improved the water-use efficiency in forests [71]; thus, a limited factor, i.e., water, relieved the restricted effects of vegetation growth in China. In recent decades, industrialization, urbanization, and mechanization have increased reliance on fossil fuels, which dramatically add to carbon dioxide emissions. Meanwhile, traditional production modes neglected the ecological environment and caused environmental pollution and vegetation damage. The total photosynthetic capacity of plants was dramatically decreased. Therefore, the balance between carbon storage and carbon emission was disturbed to enhance carbon dioxide concentration. In fact, north China was the traditionally water-limited growth region where large-scale greening has been observed [72]. Both ambitious afforestation and carbon dioxide concentration increase interacted to enhance the vegetation cover in fragile areas such as Loess Plateau and "Three North" regions. Nevertheless, land-use management such as afforestation still played a major role in the greening of China. Meanwhile, the degradation of vegetation also needed to be paid more attention. Because of the increase in carbon dioxide concentration, the vulnerability of vegetation cover in forest areas also possibly increased [73]. Therefore, the intensively anthropogenic activities further altered local patterns of vegetation cover.

5.2. Greening and Climate Regulation

Adequate evidence has indicated that climate change has had obvious influence on vegetation cover, including variation of precipitation and temperature. Although anthropogenic production activities have altered the original global climate, human-driven ecological projects such as afforestation, planting grass, and intensification of cropland indeed brought climate benefits. In China, vegetation increase in grassland and cropland decreases the climate temperature by -0.08 ± 0.32 °C and -0.06 ± 0.28 °C, respectively [74]. Meanwhile, due to insufficiently offset effects of reduced albedo, vegetation growth of forests revealed 0.05 ± 0.29 °C in warming [74]. Therefore, part of human-induced changes of ecosystems actually altered the climate. Furthermore, climate change influenced the condition of plant growth to affect the changes in vegetation cover.

6. Conclusions

Greening has been observed in China that has been driven by anthropogenic activities such as afforestation and intensification of cropland. Ambitious afforestation was the major factor to accelerate the large-scale greening in China. Mining and urbanization were the necessary measures to develop local economy. Therefore, land reclamation and urban greening were implemented to compensate the loss of vegetation due to occupation and damage. Land abandonment influenced the vegetation cover and spatial structure and reduced the efficiency of land use. Land consolidation optimized the spatial structure and improved land use efficiency, thus achieving the improvement of vegetation cover. Regional natural protection maintained the self-regulation of ecosystems to achieve stable increase in vegetation cover. Intensification of cropland that was driven by intensively anthropogenic input increased the production, and proper fallowing achieved sustainable development. Fire could dramatically alter the vegetation cover in local environment and, thus, the prevention of fire was implemented to protect the forest from man-made fire. Part of human-induced climate change also affected the changes in vegetation cover. Interaction between climate change and human activities influence vegetation cover, which still needs to be further investigated in the future.

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