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# Variation Characteristics of Land Use Change Within the Beijing–Tianjin–Hebei Region During 1985–2022

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**Abstract:** Land use change generally varies greatly among functional zones in a large area. This study reveals land use change characteristics across seven functional zones in the Beijing–Tianjin–Hebei region during 1985–2022 based on the latest land use planning data, with the land use dynamic degree, transfer matrix, and comprehensive index of land use intensity. Results suggested cropland, forest land, grassland, and built-up land were dominant land use types in most functional zones, generally with significant decreases in cropland and grassland and noticeable increases in built-up land and forest land. Besides, single land use dynamics of built-up land and forest land were generally above 2.00% and 0.40%, while that of grassland and cropland was generally below zero in most functional zones. Comprehensive land use dynamics were very high in the Central Core Functional Zone (Region IV), Bashang Plateau Ecological Protection Zone (Region I), and Eastern Coastal Development Zone (Region III), peaking above 0.70%, and were low in other functional zones. Additionally, the land use degree increased slowly from 267.28 in 1985 to 274.17 in 2022 on average, varying remarkably among various functional zones. These findings provide a firm foundation for formulating more targeted land management policies across various functional zones.

**Keywords:** land use change; functional zone; Beijing–Tianjin–Hebei region; land use dynamics; land use transfer; land use degree

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## 1. Introduction

The utilization mode and intensity of land resources have evolved greatly along with rapid economic development and acceleration of urbanization around the world [1]. Land use change as a direct interaction between human beings and the natural environment has significant impacts on global and regional sustainable development [2]. The global land use structure has undergone significant alteration, leading to increasingly prominent human–land conflicts in many areas, and land use change has been an essential research issue in the field of global change [3,4]. In particular, the International Geosphere–Biosphere Program (IGBP) and the International Human Dimensions Program on Global Environmental Change (IHDP) launched the Land Use and Land Cover Change (LUCC) research project in the 1990s, making land use change and its effects a core focus in the ecological and environmental fields [5,6]. Land use change has profoundly affected regional ecological environments, socioeconomic structures, and global climate change [7]. Research on land use change has become central to understanding regional ecological shifts, socioeconomic development, and sustainable resource management [8]. Accurate and timely information on land use change is crucial for understanding trends in regional environmental change [9]. In-depth research into the characteristics of land use change holds significant practical value for formulating scientific and reasonable land management policies for achieving sustainable regional development [10,11].

Scholars at home and abroad have conducted extensive and in-depth explorations of land use change, as it is one of the most important research topics in the field of global change [8,12]. First, scholars have carried out a significant number of studies on the characteristics of past and future land use changes with various methods [13]. For instance, Westlund and Nilsson (2022) investigated the agricultural transformation and the spatiotemporal distribution of land use in the Stockholm region, revealing the impacts of urbanization on the quantity and quality of regional agricultural land [14]. Shiferaw et al. (2021) quantified the changes in ecosystem service values due to land use change in the Gojeb River Basin, revealing the important influence of natural and human factors on land use and ecosystem service values [15]. Besides, there has been increasingly widespread application of cutting-edge technologies, e.g., the 3S technology in the research of land use change [16]. For example, Das and Angadi (2020) revealed the effects of different land use types on surface temperature in the Barrackpore subdivision based on the remote sensing data [17]. In addition, scholars have produced a vast array of high-resolution land use data products using remote sensing technology, e.g., ESA GlobCover (ESAGC), China Land Cover Dataset (CLCD), and GlobeLand30 (GLC30), which provide an important foundation for more accurate research on the characteristics of land use change [18]. Moreover, the development of various ecological models has provided a significant basis for revealing the impacts of land use change on the ecological environment [19]. For example, Gomes et al. (2021) conducted scenario simulations of future land use change and revealed its effects on habitat quality in Lithuania using the cellular automata model and the InVEST model [20].

China has experienced significant land use change along with the ongoing advancement of rapid urbanization and industrialization, especially in the Beijing–Tianjin–Hebei region, one of the most densely populated areas [21]. The Beijing–Tianjin–Hebei region, as the political, economic, and cultural core of China, plays a crucial role in the overall development of this country [22]. However, the conflict between humans and land is pronounced in this region, which has experienced significant land use change along with the acceleration of urbanization and the continuous increase in population [23]. The land use patterns in this region face unprecedented pressure and challenges, and the Chinese government proposed the Beijing–Tianjin–Hebei coordinated development strategy in 2018, aiming to enhance the overall development quality and ecological environment carrying capacity of this region [24]. The Beijing government released the "Urban Master Planning of Beijing City (2016–2035)" in 2018, and the government of Hebei Province published the "14th Five-Year Plan for the Construction of Ecological and Environmental Support Areas in the Beijing–Tianjin–Hebei Region" in 2021 in order to realize this strategy. The Beijing–Tianjin–Hebei region has been divided into different functional zones under this framework, which provides an essential foundation for regional land resource management [25,26]. However, there is still a lack of in-depth research on the up-to-date variation characteristics of land use change across these various functional zones, since most of the previous research was generally based on the administrative units or the whole Beijing–Tianjin–Hebei region [1,9]. There is an urgent need to accurately reveal the long-term variation characteristics of land use change across these various functional zones with the latest land use data for better supporting the implementation of the Beijing–Tianjin–Hebei coordinated development strategy [27]. This study aimed to accurately reveal the variation characteristics of land use change in the whole Beijing–Tianjin–Hebei region and different functional zones during 1985–2022 based on the latest land use data. This study employed multiple methods, such as the land use dynamic degree, transfer matrix, and comprehensive index of land use intensity, to quantitatively describe various characteristics of land use change. The findings of this study can provide an important theoretical basis for the optimized allocation of land resources in the Beijing–Tianjin–Hebei region and promote the implementation of the Beijing–Tianjin–Hebei coordinated development strategy.

## 2. Materials and Methods

### *2.1. Study Area*

The Beijing–Tianjin–Hebei region is located in northern China (36°5′–42°40′ N, 113°27′–119°50′ E), with a total area of about 215,654.07 km$^2$ [26,27]. There is complex topography in this region, with elevations decreasing from northwest to southeast (Figure 1). There are mainly mountains and plateaus in the west and north parts, and plains in the central, east, and south parts of this region [28]. There is a typical temperate continental monsoon climate in this region, with higher temperatures and more precipitation in summer. The Beijing–Tianjin–Hebei region is one of the three urban agglomerations in China, accounting for about 2.25% of the national total land area, but 7.77% of the national total population and 8.33% of the national total GDP. Meanwhile, the northern part of this region is the main ecological barrier of the North China Plain, which plays an important role in guaranteeing the ecological safety the Beijing–Tianjin–Hebei region, and even North China. However, the rapid socioeconomic development and population growth have led to considerable land use change in the Beijing–Tianjin–Hebei region, and the increasing occupation of ecological space by human production and living space has caused a series of ecological and environmental problems. In particular, the irrational exploitation and utilization of resources in the northern part of the Beijing–Tianjin–Hebei region has caused serious degradation of grassland ecosystems for a long time, which has been a major source of sand and dust storms in Beijing and even North China.

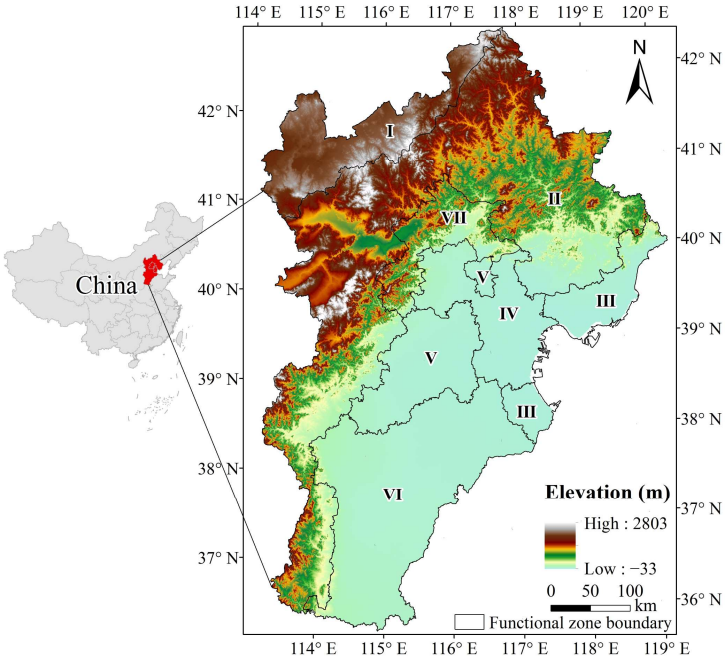


**Figure 1.** Location of the study area. Note: Bashang Plateau Ecological Protection Zone (Region I), Yanshan-Taihang Mountains Ecological Cultivation Zone (Region II), Eastern Coastal Development Zone (Region III), Central Core Functional Zone (Region IV), Beijing–Tianjin Ecological Transition Zone (Region V), Low Plain Ecological Restoration Zone (Region VI), and Northwest Beijing–Tianjin Ecological Cultivation Zone (Region VII).

A series of major ecological restoration projects have been implemented in the Beijing–Tianjin–Hebei region since 2000 to strengthen ecological protection and restoration, but the ecological safety situation is still very serious [29]. Beijing and Hebei Province released the "Urban Master Planning of Beijing City (2016–2035)" and "14th Five-Year Plan for the Construction of Ecological and Environmental Support Areas in the Beijing–Tianjin–Hebei Region" in order to further solve the ecological and environmental problems. The Beijing–Tianjin–Hebei region is accordingly divided into seven

functional zones, i.e., the Bashang Plateau Ecological Protection Zone (Region I), Yanshan-Taihang Mountains Ecological Cultivation Zone (Region II), Eastern Coastal Development Zone (Region III), Central Core Functional Zone (Region IV), Beijing–Tianjin Ecological Transition Zone (Region V), Low Plain Ecological Restoration Zone (Region VI), and Northwest Beijing–Tianjin Ecological Cultivation Zone (Region VII; Figure 1). It is necessary to take targeted land management measures according to the specific characteristics of land use change in these functional zones in order to further improve the ecological environment effectively [30].

### *2.2. Data Sources and Preprocessing*

This study utilized various datasets, such as land use data and administrative boundary data. Specifically, the land use data used in this study were derived from the "30 m Annual Land Cover Datasets and Its Dynamics in China from 1985 to 2022" (https://zenodo.org/records/8176941, accessed on 30 June 2024), with the overall accuracy of 79.31%, and more details can be found in the literature [31]. This study merged wetland into the water body since there was minimal wetland area within the study region. Besides, the administrative boundary data were obtained from the Resource and Environmental Science Data Platform of the Chinese Academy of Sciences (https://www.resdc.cn/, accessed on 30 July 2024). In addition, the functional zoning boundary data were derived on the basis of the "Hebei Province Territorial Spatial Planning (2021–2035)", the "14th Five-Year Plan for Hebei Province's Support Area for Ecological Environment in the Beijing–Tianjin–Hebei Region", the "Beijing City Master Planning (2016–2035)", and the administrative boundary data.

### *2.3. Methodology*

This study calculated the area of each land use type in the entire study region and within each functional zone in different years, and the top-three land use types in terms of area for each year were identified as the dominant land use types. Then, this study calculated the single and comprehensive land use dynamic degree for the entire study area and each functional zone over the entire study period and during different periods, as follows [32]:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

$$LC = \left[ \frac{\sum_{i=1}^{n} \Delta LU_{i-j}}{2\sum_{i=1}^{n} LU_i} \right] \times \frac{1}{T} \times 100\% \quad (2)$$

where $K$ represents the single dynamic degree of a particular land use type over the study period, $U_a$ and $U_b$ are the area of a particular land use type at the beginning and end of the study period, respectively, $T$ is the time interval of land use change, $LC$ represents the comprehensive land use dynamic degree, $\Delta LU_{i-j}$ is the absolute value of the area of land converted from the $i$th type to the $j$th type during the study period, and $LU_i$ represents the area of the $i$th land use type at the beginning of the study period [33,34].

Subsequently, this study generated the land use transfer matrix for the entire study region and each functional zone during 1985–2022 with the spatial analysis tool in the ArcGIS 10.2 software to reveal the structural characteristics of regional land use change and conversion direction of each land use type. Finally, the study calculated the land use degree for the entire study region and each functional zone during the entire study period and different periods with the following formula:

$$La = 100 \times \sum_{i=1}^{i=n} A_i \times C_i \quad (3)$$

where $La$ is the composite index of land use degree, ranging between 100 and 400, $n$ is the number of land use types, $A_i$ refers to the land use classification index for the level $i$, which was determined according to the literature [35,36], and $C_i$ is the area percentage of the land use classification of the $i$th level.

## 3. Results

### *3.1. Variation Characteristics of Dominant Land Use Types*

Dominant land use types in the study area included cropland, forest land, grassland and built-up land, which accounted for over 98% of the total land area (Figure 2). Specifically, the proportion of cropland was consistently the highest but showed a stable declining trend, decreasing from 53.81% in 1985 to 43.61% in 2022. Forest land consistently held the second-highest proportion, increasing steadily from 19.56% in 1985 to 24.89% in 2022. The third-ranked land use type was grassland before 2020 and built-up land after 2020. The proportion of grassland declined slowly from 18.00% in 1985 to 16.11% in 2015. However, it then declined significantly, leading to a drop to fourth place in 2020. The proportion of built-up land ranked fourth in most years but showed a significant increasing trend, rising from 6.81% in 1985 to 15.29% in 2022, increasing much more rapidly than that of the other land use types. The area of built-up land nearly trebled during the study period, surpassing that of grassland and ranking third in 2020.

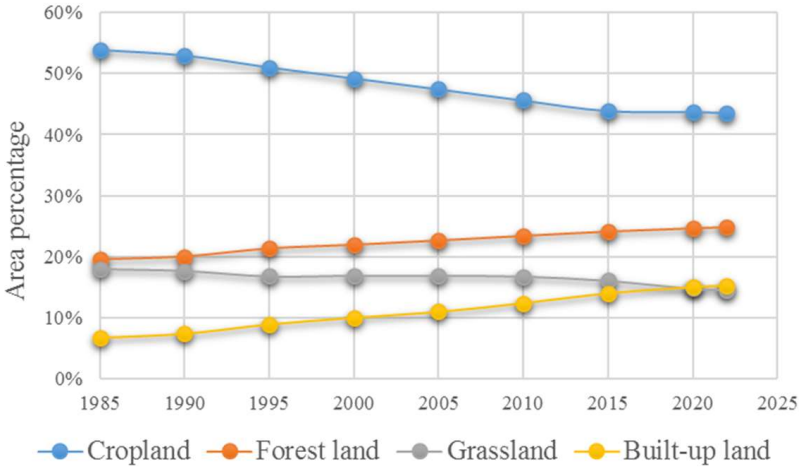


**Figure 2.** Variation of area percentages of dominant land use types in the entire study area during 1985–2022.

There was significant spatial heterogeneity of the land use in the study area, but with a relatively stable spatial pattern during the study period (Figure 3). Specifically, cropland was concentrated in Regions III, IV, V, and VI and was scattered in the western part of Region II and its boundary areas adjacent to Regions V and VI. Forests were mainly located in Regions II and VII, primarily along the Yanshan-Taihang Mountains. Grassland was concentrated in most parts of Region I and the northwestern part of Region II, with sparse distribution in other parts of Region II. Built-up land was mainly concentrated in Regions III, IV, V, and VI, including urban areas of Beijing, Tianjin, and Tangshan, as well as cities along rail lines, such as Shijiazhuang, Xingtai, and Handan. Built-up land exhibited a clustered distribution in county towns and a more scattered distribution across extensive plain areas in these regions. By contrast, built-up land was primarily clustered in a few parts of Regions I and II. The water bodies were mainly located in coastal regions of Regions III and IV and mountainous areas of Regions II and VII, while the water bodies in Regions V and VI primarily consisted of reservoirs in flat areas. Overall, the spatial distribution of dominant land use types was closely related to topography, where cropland and built-up land concentrated in lower-elevation plains and the forest and grassland were primarily in higher-elevation mountains and plateaus.

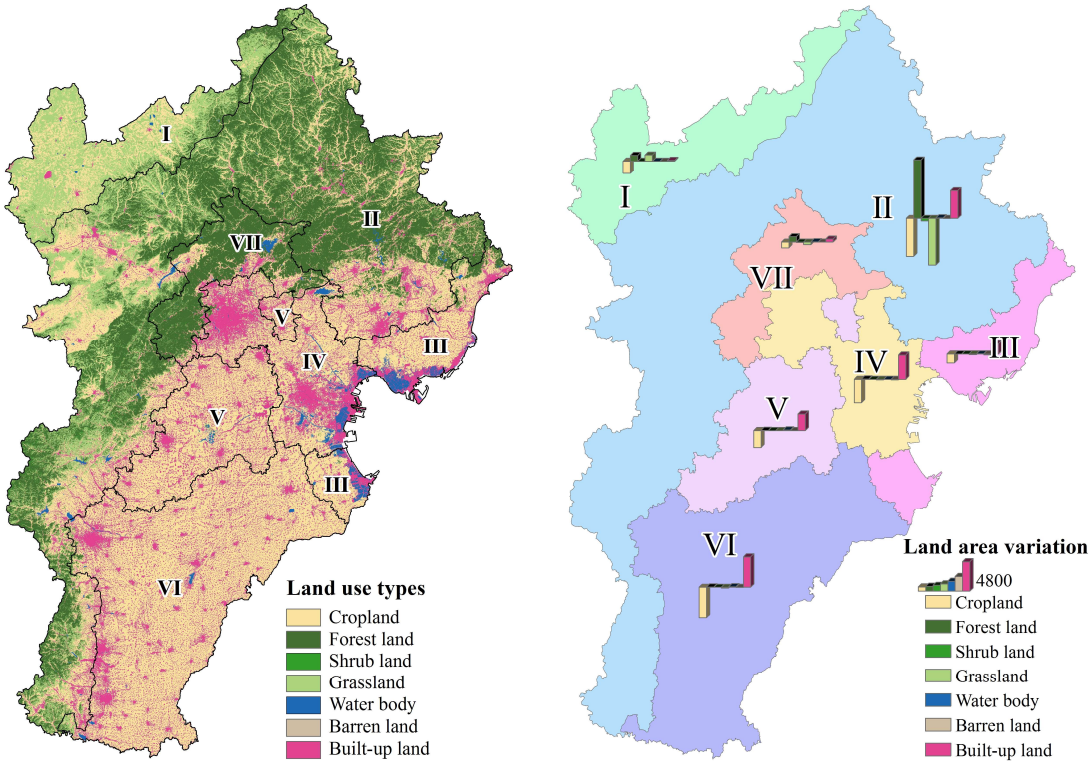


**Figure 3.** Spatial pattern of land use types in 2022 and land area variation across functional zones during 1985–2022 (unit: km$^2$) in the Beijing–Tianjin–Hebei region. Note: Bashang Plateau Ecological Protection Zone (Region I), Yanshan-Taihang Mountains Ecological Cultivation Zone (Region II), Eastern Coastal Development Zone (Region III), Central Core Functional Zone (Region IV), Beijing–Tianjin Ecological Transition Zone (Region V), Low Plain Ecological Restoration Zone (Region VI) and Northwest Beijing–Tianjin Ecological Cultivation Zone (Region VII).

There was a remarkable difference in the area variation of various land use types in the study area during 1985–2022 (Figure 3). Firstly, cropland changed by −22,016.7 km$^2$ in the study area, which occurred in all regions, particularly in Regions II, IV, and VI, which accounted for 27.86%, 22.38%, and 17.20% of the cropland decrease area, respectively. Besides, built-up land increased significantly by 18,293.51 km$^2$ in total, 26.80%, 24.61%, and 21.43% of which occurred in Regions VI, II, and IV, respectively. In addition, forest land increased by 11,496.88 km$^2$, 26.80%, 24.61%, and 21.43% of which occurred in Regions II, I, and VII, respectively. Moreover, grassland changed by −7308.96 km$^2$, most significantly in Regions II and I, which accounted for 103.27% and −13.60% of the grassland decrease area, i.e., Region I experienced a notable increase rather than decrease of grassland. By contrast, the other land use types only experienced slight variation during the study period. Specifically, shrub land changed by −485.09 km$^2$, 84.94% and 13.46% of which occurred in Regions II and VII, respectively, but there was a slight increase of shrub land in Regions IV, V, and VI. The water body increased by 304.36 km$^2$, 34.87%, 31.26%, and 25.60% of which occurred in Regions V, VI, and II, respectively, while it decreased slightly in Regions I and IV. Meanwhile, bare land changed by −284 km$^2$, 55.85% and 25.02% of which occurred in Regions III and IV, respectively, but it experienced a slight increase in Region VII.

There were significant differences and similarities in dominant land use types and their variations among various functional zones. For example, dominant land use types were grassland, cropland, and forest land in both Regions I and II, jointly accounting for over 98% of the regional area (Figure 4). These dominant land use types showed different and stable ranking sequences but very similar variation trends in Regions I and II. Region I is located in the northwestern part of the study area, covering an area of 18,980.28 km$^2$, with a relatively high altitude and low annual precipitation. The grassland area in Region

I decreased slowly from 9757.15 km$^2$ in 1985 to 9124.27 km$^2$ in 1995 and increased to 11,173.91 km$^2$ in 2015. Thereafter, it gradually declined to 10,752.06 km$^2$ by 2022, showing an overall increasing trend with significant fluctuations and consistently ranking first. The cropland area in Region I increased slowly from 7773.16 km$^2$ in 1985 to 8276.74 km$^2$ in 1995, but then it significantly declined to 5630.50 km$^2$ in 2015 and, thereafter, remained relatively stable. By contrast, the forest land area in Region I was relatively small, but it showed a slow and steady growth trend, increasing from 1241.05 km$^2$ in 1985 to 2187.39 km$^2$ in 2022.

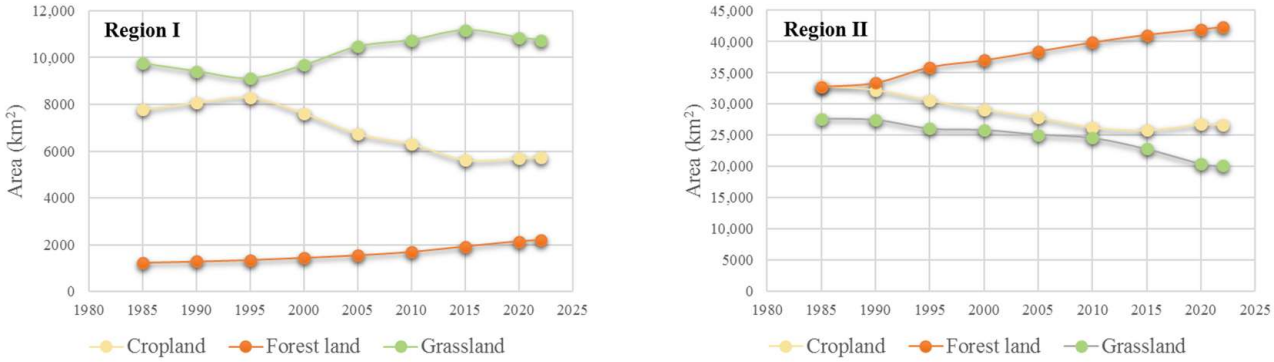


**Figure 4.** Area variations of dominant land use types in the Bashang Plateau Ecological Protection Zone (Region I) and Yanshan-Taihang Mountains Ecological Cultivation Zone (Region II).

Region II is located near the northern and western boundaries of the study area, covering an area of 97,086.03 km$^2$, where dominant land use types have consistently been forest land, cropland, and grassland, jointly accounting for over 90% of the regional area. The forest land area was 32,771.66 km$^2$ in 1985, which was slightly lower than the cropland area, but it expanded continuously and reached 42,305.11 km$^2$ in 2022, showing a stable increasing trend and ranked first in most years. By contrast, the cropland area in Region II decreased remarkably from 32,832.03 km$^2$ in 1985 to 25,858.19 km$^2$ in 2015, and then slowly increased to 26,698.25 km$^2$ by 2022. Additionally, the grassland area in Region II declined gradually from 27,649.94 km$^2$ in 1985 to 20,101.04 km$^2$ in 2022, but it consistently ranked third. Moreover, it is notable that there was no single dominant land use type. This is likely because Region II primarily encompasses the Yanshan-Taihang Mountains, where the complex topography and relatively fragile ecological conditions greatly limited the land development.

Regions III, IV, V, and VI are located in the plain areas of the study area, covering areas of 11,501.44 km$^2$, 16,447.50 km$^2$, 16,663.67 km$^2$, and 43,338.06 km$^2$, respectively, which were generally consistent in the dominant land use types and their variation trends (Figure 5). First, dominant land use types in Regions III, IV, and V included cropland, built-up land, and the water body, while that in Region VI included cropland, built-up land, and grassland, with a stable ranking of these dominant land types throughout the study period. Although the third dominant land use type was different among these regions, its area and proportion were quite small. Besides, cropland showed a significant downward trend and built-up land increased rapidly in Regions III, IV, V, and VI. Specifically, the cropland area in Regions III, IV, V, and VI decreased from 8379.91 km$^2$, 12,191.28 km$^2$, 14,738.98 km$^2$, and 37,171.54 km$^2$ in 1985 to 6935.50 km$^2$, 8404.53 km$^2$, 11,986.69 km$^2$, and 32,244.17 km$^2$ in 2022, respectively. Conversely, built-up land in these regions increased from 1299.02 km$^2$, 2895.56 km$^2$, 1826.15 km$^2$, and 5608.30 km$^2$ in 1985 to 2983.15 km$^2$, 6815.07 km$^2$, 4482.37 km$^2$, and 10,511.53 km$^2$ in 2022, respectively. Additionally, the area of the water body in Regions III and IV consistently ranked third, remaining stable, with some fluctuations. Meanwhile, the area of the water body in Region V and area of grassland in Region VI ranked third in most years and only experienced slight fluctuations throughout the study period.

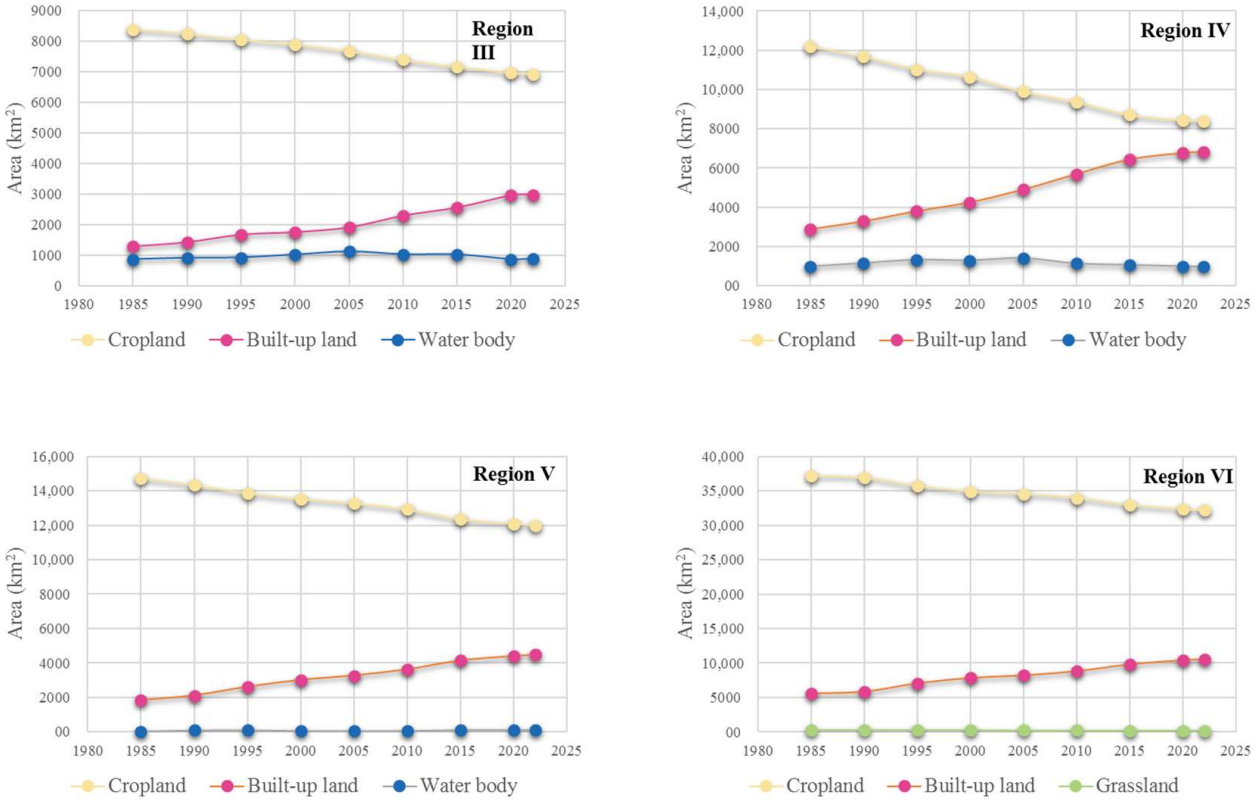


**Figure 5.** Area variations of dominant land use types in the Eastern Coastal Development Zone (Region III), Central Core Functional Zone (Region IV), Beijing–Tianjin Ecological Transition Zone (Region V), and Low Plain Ecological Restoration Zone (Region VI).

Region VII is located in the mountainous area of Beijing Municipality and Tianjin Municipality, covering a total area of 11,636.78 km$^2$, where dominant land use types included forest land, cropland, grassland, and built-up land during the study period (Figure 6). The forest land area in Region VII initially increased rapidly from 7224.56 km$^2$ in 1985 to 7830.96 km$^2$ in 1995, and then slightly increased and reached 8102.04 km$^2$ by 2022. By contrast, cropland showed a steady declining trend during the study period, decreasing from 2967.01 km$^2$ in 1985 to 2025.57 km$^2$ in 2022. It is notable that the third dominant land use type in Region VII was grassland during 1985–1995 and built-up land during 2000–2022. In fact, there were remarkable differences in the land use change between Region VII and other functional zones. Although Region VII is situated in two municipalities with the highest urbanization level, it is designated as an ecological conservation area, with considerable limitations on the regional land development. Nevertheless, there was still significant expansion of built-up land in this region, along with rapid urbanization. The area of built-up land grew rapidly from 398.45 km$^2$ in 1985 to 572.40 km$^2$ in 2000, surpassing the grassland area and finally reaching 890.84 km$^2$ by 2022. Conversely, the grassland area in Region VII decreased from 774.74 km$^2$ in 1985 to 367.12 km$^2$ in 2022, the proportion of which decreased from 6.66% in 1985 to 3.15% in 2022.

### *3.2. Variations of Land Use Dynamics*

There were significant differences in the single land use dynamics among dominant land use types within the study area (Figure 7). Specifically, the single land use dynamics of cropland were below zero across all periods, with an average of −0.53%, indicating continuous shrinkage of cropland. The most remarkable shrinkage of cropland occurred during 1990–2015, with the single land use dynamics of cropland exceeding −0.7%. Although the single land use dynamics of cropland were not the highest, the total area was the largest in the study area, highlighting the significant impacts of urbanization and other factors

on cropland. In contrast, the average single land use dynamics of forest land from 1985 to 2022 was 0.64%, remaining above zero across all periods, indicating steady expansion of forestry resources and effective ecological protection. Specifically, the single land use dynamics of forest land peaked at 1.33% during 1990–1995 and fluctuated between 0.40% and 0.67% during other periods. The average single land use dynamics of grassland was −0.56% during 1985–2022, remaining negative across all periods except 1995–2000, indicating a continuous shrinkage of grassland. This may be due to the fact that the grassland was mainly concentrated in Region I, an ecologically fragile region very sensitive to the increasingly significant climate change and human activities. It is very notable that the average single land use dynamics of built-up land was 2.21%, exceeding 1.00% during most periods and indicating a rapid expansion trend of built-up land. The most significant increase of built-up land occurred during 1990–1995 and 2005–2015, with single land use dynamics exceeding 4.00% and 2.50%, respectively.

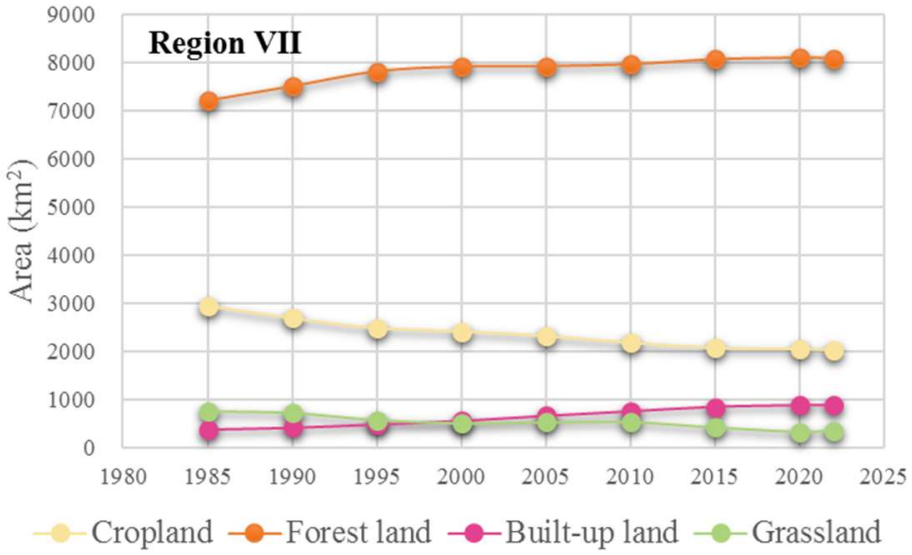


**Figure 6.** Area variations of dominant land use types in the Northwest Beijing–Tianjin Ecological Cultivation Zone (Region VII).

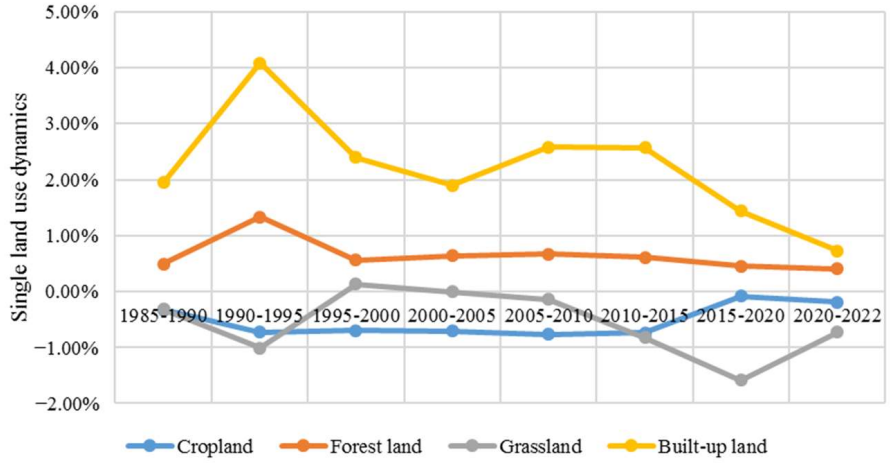


**Figure 7.** Variation of the single land use dynamics of dominant land use types in the entire study area during 1985–2022.

The period during 1990–1995 witnessed the most dramatic changes in dominant land use types in the study area, which was primarily due to significant built-up land expansion. In fact, industrialization and urbanization in the Beijing–Tianjin–Hebei region progressed

rapidly in the 1990s, especially since the "Southern Tour Speech" of Xiaoping Deng in 1992, which led to significant urban population growth and significant urban built-up land expansion [37]. Previous research also suggested the urban built-up land area in the Beijing–Tianjin–Hebei region increased by 71% during 1990–2000, most of which was converted from cropland around cities [38]. Meanwhile, some grassland and other land use types, especially around the cropland, were converted into cropland to ensure the food security [39]. It is notable that a series of policies, such as the "Cropland Quality Protection and Enhancement Action Plan" implemented in 2015, led to some control over the cropland shrinkage. By contrast, grassland was not effectively protected during the study period. In fact, grassland was more sensitive to climate change and human disturbance and was scattered in most parts of the study region, making it very prone to conversion into other land use types. In particular, ecological projects, such as the "Three-North Shelterbelt Program" since 1978, have effectively promoted the continuous forest land expansion, while the newly added forest land was primarily sourced from grassland [40]. Additionally, industries in most parts of the study area, except Region I, depend slightly on grassland, where grassland protection is generally not so strict, leading to continuous occupation of grassland by other land use types, especially during 2015–2020.

The comprehensive land use dynamics of the entire study area and various functional zones generally showed a subtle bimodal curve throughout the study period (Figure 8). First, the comprehensive land use dynamics of the entire study area was 0.38% on average. It reached 0.60% and 0.48% during 1990–1995 and 2010–2015, respectively, indicating a significant restructuring and adjustment of land use during these periods, while it reached its lowest value (0.22%) during 2020–2022, reflecting a relative slowdown and stabilization of land use change. Besides, the comprehensive land use dynamics in Regions II, VI, and VII, accounting for the largest proportion of the study area, aligned closely with that of the entire study area, with the average values of 0.42%, 0.31%, and 0.36%, respectively. These regions saw their comprehensive land use dynamics peak during 1990–1995, followed by a subtle peak during 2010–2015 or 2015–2020. In contrast, the comprehensive land use dynamics in Regions I, III, IV, and V all displayed a distinct bimodal curve with significant fluctuations, with the average values of 0.53%, 0.45%, 0.69%, and 0.46%, respectively. Specifically, comprehensive land use dynamics of Region I reached 0.96% and 0.72% during 2000–2005 and 2010–2015, respectively, and thereafter declined rapidly to 0.27% during 2020–2022. Similarly, comprehensive land use dynamics of Region III peaked at 0.71% and 0.70% during 2005–2010 and 2015–2020, respectively, before dropping to 0.21% during 2020–2022. It is notable that Region IV had the highest comprehensive land use dynamics, peaking at 0.86% and 0.97% during 1990–1995 and 2005–2010, respectively, and then quickly declining to 0.19% during 2020–2022. The comprehensive land use dynamics in Region V reached 0.61% and 0.69% during 1990–1995 and 2010–2015, respectively, before dropping to 0.31% during 2015–2020 and stabilizing during 2020–2022.

### *3.3. Land Use Transfer Within the Entire Study Area*

There were 12 major land use transfer types in the study area, which showed significant spatial heterogeneity (Figure 9). For example, the conversion of cropland to built-up land mainly occurred in the plain areas of the study area, e.g., Regions III, IV, V, and VI, especially in peripheral areas of existing cities, such as Beijing, Tianjin, Shijiazhuang, and Tangshan. The conversion of cropland to built-up land in Regions I and II was generally distributed in points and bands, respectively. Besides, the conversion of grassland to forest land mainly occurred in Regions II, I, and VII, especially in mountainous areas of these regions. In addition, the conversion of cropland to grassland mainly occurred contiguously in Region I and discretely in Region II. Meanwhile, the conversion of grassland to cropland was also mainly discretely distributed in Regions I and II, but it showed continuous distribution in some areas. Moreover, the other land use transfer types were relatively small in area, and all of them showed obvious regional differences.

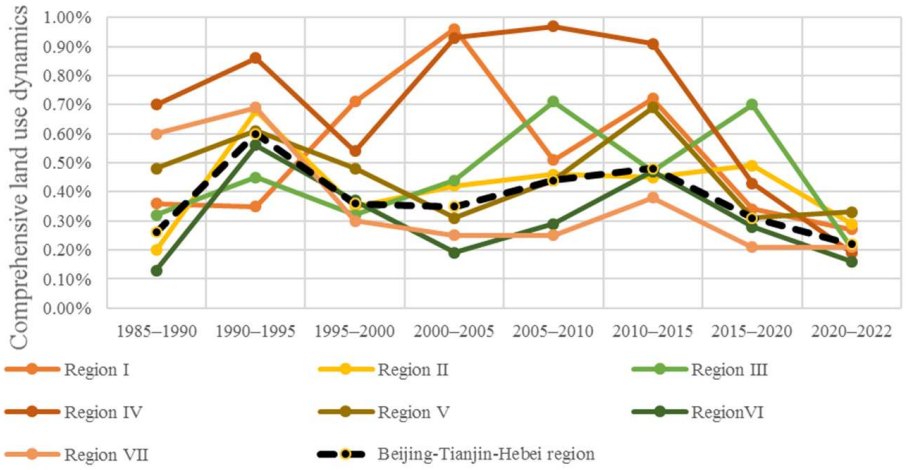


**Figure 8.** Comprehensive land use dynamics during 1985–2022. Note: Bashang Plateau Ecological Protection Zone (Region I), Yanshan-Taihang Mountains Ecological Cultivation Zone (Region II), Eastern Coastal Development Zone (Region III), Central Core Functional Zone (Region IV), Beijing–Tianjin Ecological Transition Zone (Region V), Low Plain Ecological Restoration Zone (Region VI), and Northwest Beijing–Tianjin Ecological Cultivation Zone (Region VII).

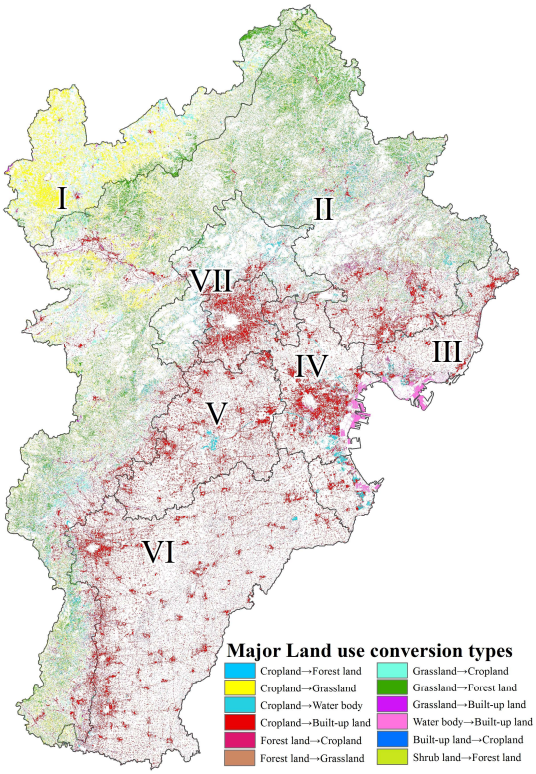


**Figure 9.** Spatial pattern of land use transfer in the study area during 1985–2022. Note: Bashang Plateau Ecological Protection Zone (Region I), Yanshan-Taihang Mountains Ecological Cultivation Zone (Region II), Eastern Coastal Development Zone (Region III), Central Core Functional Zone (Region IV), Beijing–Tianjin Ecological Transition Zone (Region V), Low Plain Ecological Restoration Zone (Region VI), and Northwest Beijing–Tianjin Ecological Cultivation Zone (Region VII).

There was remarkable land use transfer in the entire study area during 1985–2022, which was characterized by a significant decrease in cropland and grassland and noticeable increase in built-up land and forest land (Figure 10). Specifically, the area converted out of cropland reached 28,227.68 km$^2$, with conversions to built-up land, grassland, and forest

land totaling 17,835.85 km$^2$, 6408.19 km$^2$, and 3075.87 km$^2$, respectively. Meanwhile, the newly added cropland area was 6210.97 km$^2$, which was mainly derived from grassland, forest land, and built-up land, with areas of 3791.36 km$^2$, 1180.94 km$^2$, and 1038.98 km$^2$, respectively. Additionally, the area converted out of grassland reached 15,153.72 km$^2$, which was primarily transformed into forest land and cropland, with areas of 10,456.68 km$^2$ and 3791.36 km$^2$, respectively. Meanwhile, the newly added grassland area was 7844.75 km$^2$, which was mainly converted from cropland and forest land. Moreover, there were limited transfers of other land use types, including the water body, bare land, and shrub land.

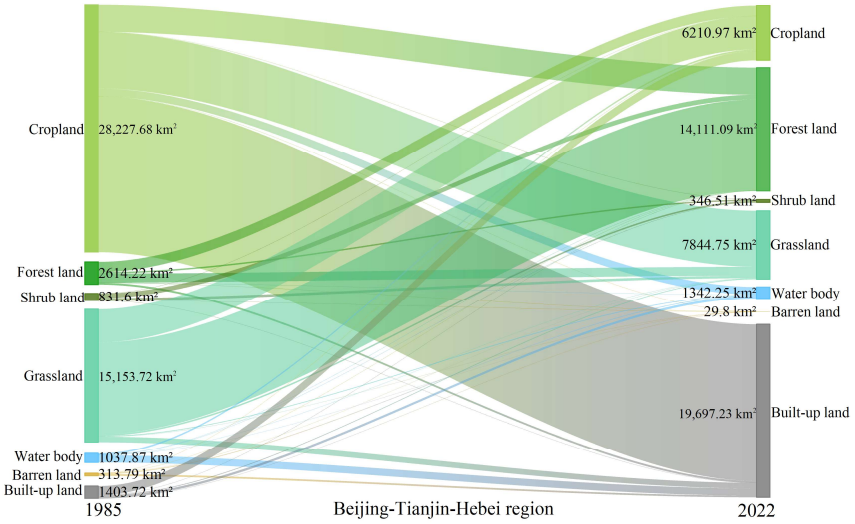


**Figure 10.** Sankey map of land use transfer of the entire study area during 1985–2022.

There were both similarities and differences in the land use transfer among different parts of the study area during the study period (Figure 11). Region I was primarily characterized by the transformation of cropland and grassland to other land use types. Specifically, the area converted out of cropland reached 3251.74 km$^2$, 3121 km$^2$ of which was converted into grassland. The newly added cropland area was only 1220.85 km$^2$, primarily sourced from grassland, resulting in a net decrease of approximately 2030.89 km$^2$ in total cropland area in Region I, indicating significant achievements in ecological protection projects, such as the project of returning cropland to forest and grassland. Besides, the area converted out of grassland reached 2254.06 km$^2$, primarily converted into cropland and forest land, with areas of 1199.036 km$^2$ and 960.8319 km$^2$, respectively, leading to a total increase in the grassland area of 993.82 km$^2$. While the overall grassland area in the entire study area significantly decreased, only Region I saw a remarkable increase, accounting for −13.60% of the decrease in total grassland area of the study area. Additionally, Region I accounted for 8.24% of the total increase in forest land in the entire study area, where the significant increases in grassland and forest land indicated the effectiveness of ecological conservation policies in this region. Other land use types in Region I showed minor variation, but the area of built-up land increased from 97.87 km$^2$ in 1985 to 235.17 km$^2$ in 2022, with a growth of 140.29%, indicating that urbanization and infrastructure development have increasingly influenced land use in this region.

Region II exhibited more complex land use transfer, primarily characterized by a significant reduction in grassland and cropland and a noticeable increase in forest land and built-up land (Figure 12). Specifically, the area converted out of grassland in Region II reached 11,977.695 km$^2$, 2411.01 km$^2$ and 8930.74 km$^2$ of which were transformed into cropland and forest land, respectively. The newly added grassland area in Region II was only 4429.25 km$^2$, largely sourced from cropland and forest land, with areas of 3177.01 km$^2$ and 928.78 km$^2$, respectively. Besides, the area converted out of cropland in Region II was 9856.63 km$^2$, which was mainly converted into built-up land, grassland, and forest land, with areas of 4228.33 km$^2$, 3177.01 km$^2$, and 2333.35 km$^2$, respectively.

The newly added cropland area in Region II was only 3722.745 km$^2$, mainly sourced from grassland and forest land, with areas of 2411.095 km$^2$ and 967.795 km$^2$, respectively. In addition, the area converted out of forest land was 2216.17 km$^2$, but the newly added area reached 11,749.235 km$^2$, primarily sourced from cropland and grassland and some shrub land, leading to a significant increase in forest land by 9533.065 km$^2$. This indicated a clear mutual conversion between grassland, cropland, and forest land in Region II during the study period. Moreover, built-up land in Region II significantly increased by 4905.50 km$^2$, primarily sourced from cropland and grassland, totaling 4228.335 km$^2$ and 456.725 km$^2$, respectively. Meanwhile, only a small amount of built-up land was converted back to cropland. Finally, there were very limited transformations of water bodies and bare land in Region II, but the area converted out of shrub land reached 715.225 km$^2$, which was primarily transformed into forest land and grassland, with areas of 458.92 km$^2$ and 254.15 km$^2$, respectively.

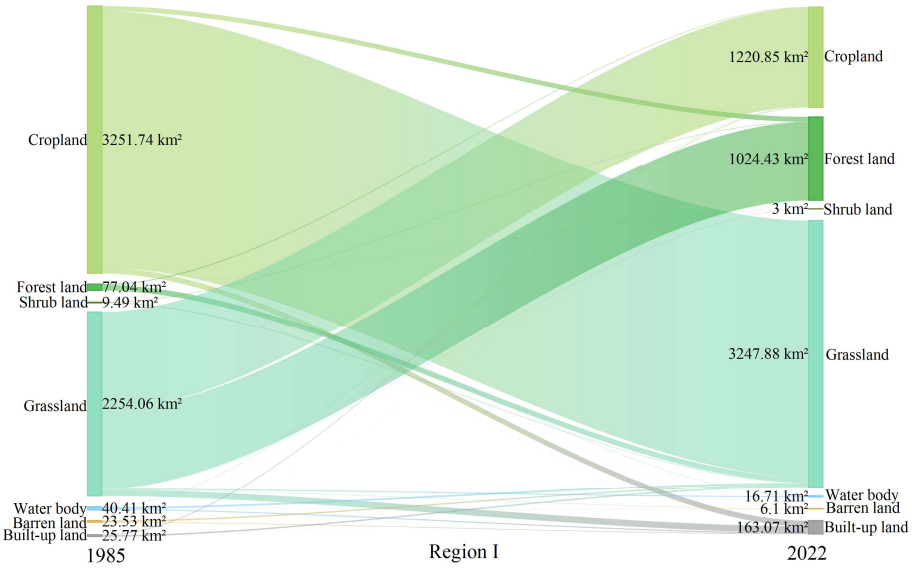


**Figure 11.** Sankey map of land use transfer of the Bashang Plateau Ecological Protection Zone (Region I) during 1985–2022.

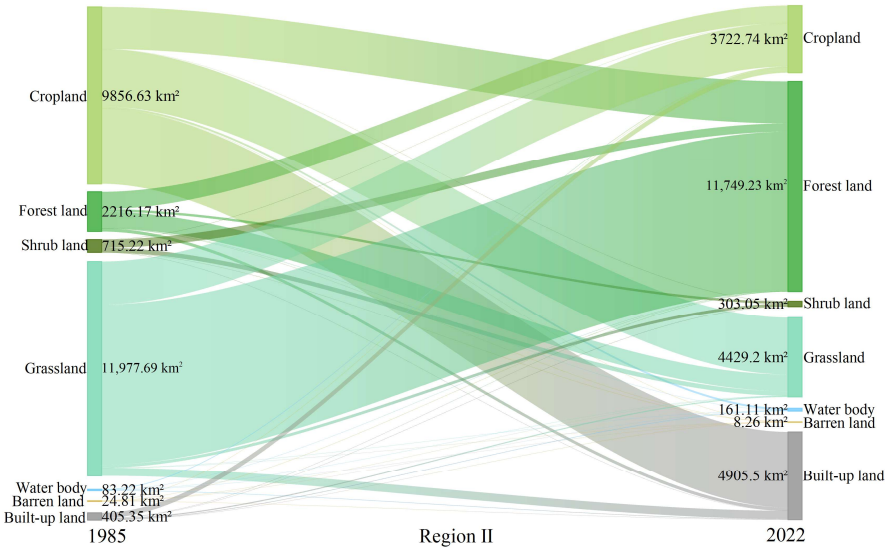


**Figure 12.** Sankey map of land use transfer of the Yanshan-Taihang Mountains Ecological Cultivation Zone (Region II) during 1985–2022.

The land use transfer in Region VII was similar to that in Region II, with similar natural conditions (Figure 13). The area converted out of cropland in Region VII was 1079.23 km$^2$, mainly converted into forest land and built-up land, with areas of 510.12 km$^2$ and 465.58 km$^2$, respectively. The newly added cropland area was only 137.67 km$^2$, mainly sourced from forest land and grassland. Besides, the area converted out of grassland in Region VII was 505.32 km$^2$, 424.85 km$^2$ of which was transformed into forest land. The newly added grassland area was very limited, reaching only 97.75 km$^2$, which was mainly sourced from cropland and shrub land. In addition, the forest land area in Region VII increased by 1019.57 km$^2$, mainly sourced from cropland, grassland, and some shrub land. Moreover, the built-up land in Region VII also significantly increased by 500.27 km$^2$, sourced mainly from cropland and partly from forest land and grassland. Region VII serves as an important water source area for Beijing and Tianjin, with many important ecological function zones and stricter land development restrictions, resulting in relatively limited land use transfer in this region. Nevertheless, the area of built-up land in Region VII still increased by approximately 123.58% from 1985 to 2022, indicating that urbanization had significant impacts on this area, and it is necessary to further strengthen land use regulation and ecological protection in this region in the future.

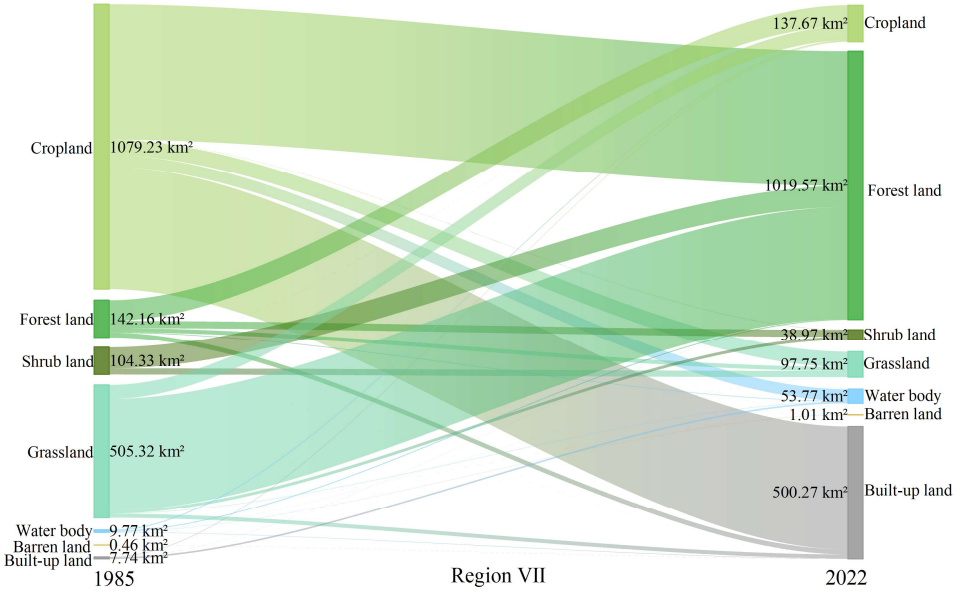


**Figure 13.** Sankey map of land use transfer of the Northwest Beijing–Tianjin Ecological Cultivation Zone (Region VII) during 1985–2022.

Regions III, IV, V, and VI are all located in plain areas, which were similarly characterized with remarkable transformations from cropland into built-up land (Figure 14). Specifically, the area converted out of cropland in Regions III, IV, V, and VI reached 1707.29 km$^2$, 3939.35 km$^2$, 2896.65 km$^2$, and 5496.67 km$^2$, respectively, most of which were converted into built-up land. Meanwhile, the newly added cropland areas in Regions III and IV were quite small, reaching only 262.92 km$^2$ and 152.77 km$^2$, respectively, sourced from various other land use types. The newly added cropland areas in Regions V and VI were also small, reaching only 144.39 km$^2$ and 569.34 km$^2$, respectively, but primarily derived from built-up land. Additionally, the newly added built-up land area in Regions III and IV reached 1891.10 km$^2$ and 4025.28 km$^2$, respectively, mainly sourced from cropland and water bodies. Meanwhile, the newly added built-up land area in Regions V and VI reached 2781.55 km$^2$ and 5429.48 km$^2$, respectively, almost entirely sourced from cropland. Moreover, the converted area of water bodies in Regions III and IV was 419.45 km$^2$ and 451.63 km$^2$, respectively, primarily converted into built-up land, while the newly added water body areas in Regions III and IV were 441.01 km$^2$ and 435.22 km$^2$, respectively,

mainly sourced from cropland and built-up land. In contrast, there were insignificant transformations of water bodies and other land use types in Regions V and VI. Overall, Regions III, IV, V, and VI all experienced a notable decrease in cropland and a significant increase in built-up land, but with the transfer areas for water bodies being larger in Regions III and IV compared to those in Regions V and VI, which may be closely related to differences in natural factors, such as precipitation, in these regions.

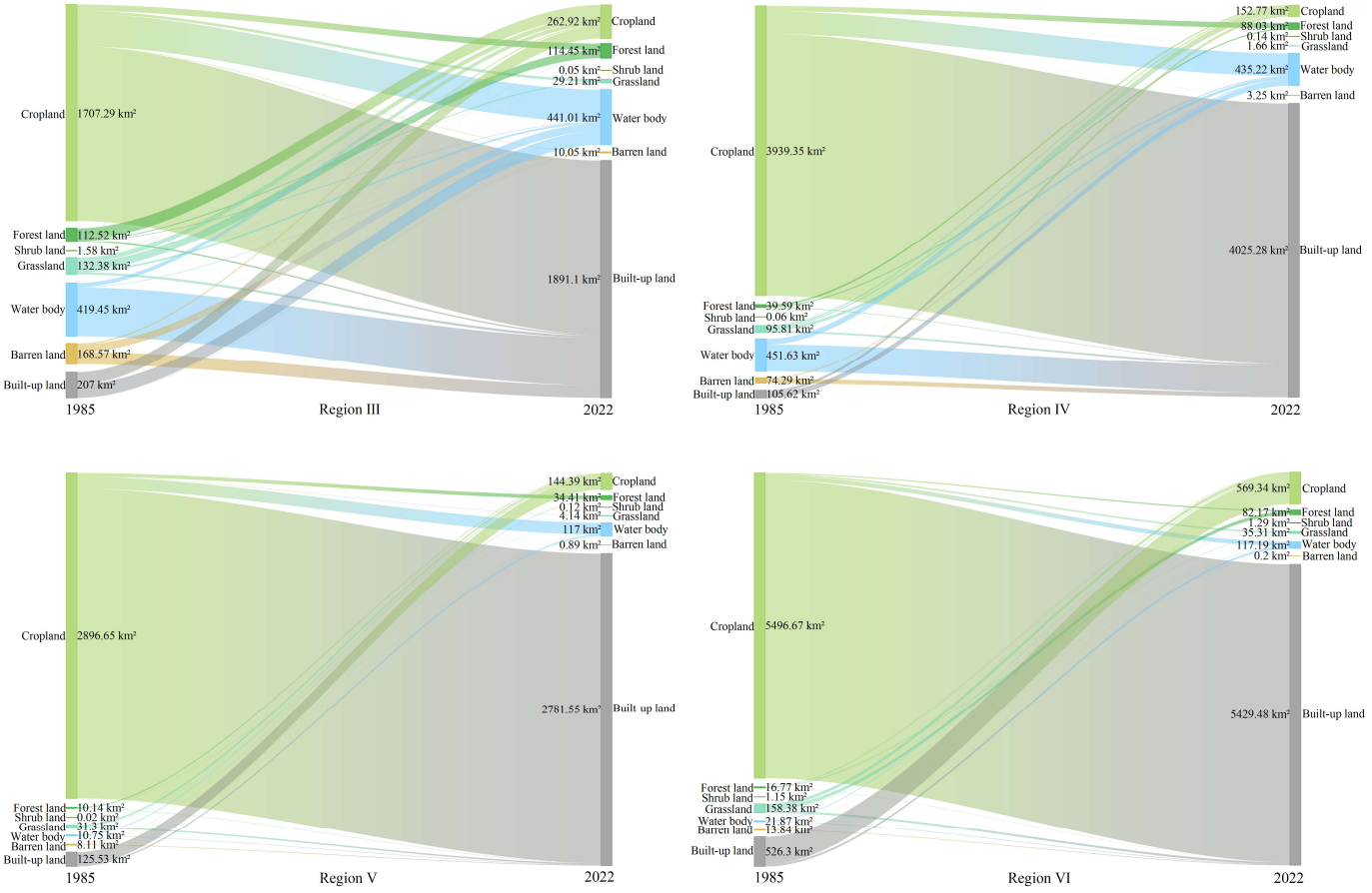


**Figure 14.** Sankey map of land use transfer of the Eastern Coastal Development Zone (Region III), Central Core Functional Zone (Region IV), Beijing–Tianjin Ecological Transition Zone (Region V), and Low Plain Ecological Restoration Zone (Region VI) during 1985–2022.

### *3.4. Variation of the Land Use Degree in the Study Area*

There was remarkable variation in the land use degree across the study area (Figure 15). Specifically, the land use degree of the entire study area showed a stable and slow growth trend, increasing from 267.28 in 1985 to 274.17 in 2022. However, there were notable differences in variation of the land use degree among different functional zones. For instance, there were relatively low land use degrees in Regions I, II, and VII, but with some differences in variation. The land use degree in Region I initially increased slightly and then declined significantly, peaking at 244.38 in 1995 and dropping to 231.69 in 2015, decreasing by 9.16 during the whole study period. Region I is the only region in the study area where the land use degree declined over the study period, which may be due to the relatively limited human activities and gradually strict ecological conservation. The land use degrees of Regions II and VII exhibited a trend of slight decline followed by a slight increase, fluctuating around approximately 240 and 231, with minimal overall changes of 2.97 and 0.37, respectively. The minor variation in the land use degrees of these regions is primarily due to geographical constraints, policy regulations, and a lack of strong economic drivers. For example, Region VII had the lowest land use degree in the study area, which

serves as an ecological conservation zone within Beijing and Tianjin and is subject to strict land use controls and limited development activity.

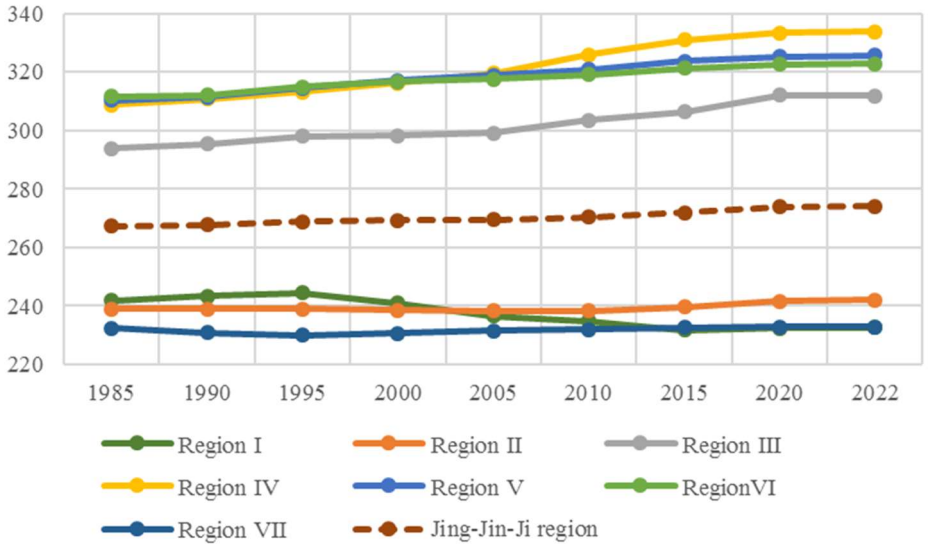


**Figure 15.** Variations in the comprehensive index of land use degree in the study area. Note: Bashang Plateau Ecological Protection Zone (Region I), Yanshan-Taihang Mountains Ecological Cultivation Zone (Region II), Eastern Coastal Development Zone (Region III), Central Core Functional Zone (Region IV), Beijing–Tianjin Ecological Transition Zone (Region V), Low Plain Ecological Restoration Zone (Region VI), and Northwest Beijing–Tianjin Ecological Cultivation Zone (Region VII).

The land use degrees in Regions IV, V, and VI were much higher and showed a remarkable growth trend. The variation in the land use degrees in these functional zones was nearly identical before 2005, increasing slowly from approximately 310 in 1985 to approximately 318 in 2005. However, the land use degree of Region IV experienced rapid growth after 2005 and reached 333.95 in 2022, increasing by 25.08 over the study period. In fact, Region IV saw the largest increase in the land use degree, largely due to significant land development and urban expansion in this region with two large cities. Meanwhile, the land use degrees in Regions V and VI continued to grow steadily after 2005, reaching 325.72 and 322.91 in 2022, with increases of 15.40 and 11.29, respectively. In fact, Regions IV, V, and VI are all economically developed or urbanized areas with rapid urbanization and economic growth, which greatly boosted the land use degrees in these regions after 2005. Additionally, the land use degree of Region III was significantly lower than those of Regions IV, V, and VI, but higher than those of Regions I, II, and VII. The land use degree in Region III increased from 293.91 in 1985 to 299.23 in 2005, with a modest rise of 5.32. However, it thereafter experienced rapid growth and reached 312.12 in 2020, with an overall increase of 18.11, marking the second largest increase. It is notable that the variation trend of the land use degree of Region III is similar to that of Region IV. This is primarily because Region III is located in the coastal area of Hebei Province, adjacent to Region IV. The rapid urbanization and economic development of major cities, including Beijing and Tianjin, in Region IV had a very significant influence on the land use change in Region III.

## 4. Discussion

The land use management policies should take into account the unique circumstances of various functional zones, which have distinct locational conditions, natural features, and urbanization levels. However, most of the previous relevant studies were generally based on administrative units, with relatively scarce research on land use change based on functional zones. This study revealed the up-to-date characteristics of land use change in various functional zones in the study area based on the latest functional zoning information and land use data. However, the spatial resolution of the land use data used in this study is

still limited due to the limitations of data availability, and it is necessary to carry out more in-depth research based on multiple-source land use data with higher spatial resolution. Nevertheless, the results of this study can still provide detailed and timely decision-making support for land management in various functional zones in the Beijing–Tianjin–Hebei region and other large regions.

It is notable that there was a significant difference in the dominant functions of different functional zones, and local land management policies should comply with the central government's regional division policies to ensure coordinated regional development. For example, Region I is a plateau region with low levels of urbanization and industrialization, where land use activities are significantly constrained by the terrain and climate conditions. With the implementation of some ecological programs, there has been remarkable expansion of grassland and forest land in this region. In particular, with the advancement of urbanization and infrastructure development in recent years, some low-efficiency cropland has been converted into forest land or other ecological land, making significant progress in improving water conservation and reducing the risk of landslides. To more effectively prevent grassland degradation and soil erosion, it is necessary to further strengthen the protection of grasslands and forest land, enhance ecological restoration, and protect biodiversity while minimizing the environmental impact of agricultural practices in this region. In particular, moderate urbanization in this region should be promoted to reduce human interference with natural ecosystems in the future.

Regions II and VII are located in the Yanshan-Taihang Mountains with complex natural conditions and abundant forest resources, which serve as ecological barriers and water conservation zones for Beijing and Tianjin. Overdevelopment of land resources in these regions can lead to serious soil erosion and ecological degradation, so land use and management policies in these regions should prioritize ecological protection. However, there are relatively sparse populations and low levels of urbanization and economic development in these regions, which greatly limit the local capacity to implement ecological protection measures. It is, therefore, necessary to improve land management policies to further promote the coordination of ecological conservation in the entire Beijing–Tianjin–Hebei region and focus more on ecological restoration, forest conservation, and water conservation in these two regions. For example, it is essential to establish appropriate ecological compensation mechanisms to encourage local residents to engage in environmentally friendly industries, such as ecological tourism and the green food industry, thus achieving a balance between ecological protection and economic development.

Regions III, IV, V, and VI are located in the plains, which include the political, economic, and cultural centers of the Beijing–Tianjin–Hebei region. These regions have abundant arable land, favorable locational conditions, convenient transportation, and high population density, making them key areas for land development. However, urban expansion in these regions has increased the demand for built-up land, leading to the occupation of large amounts of cropland and intensifying ecological pressures. Therefore, land use management in the core areas, such as Beijing and Tianjin, should adopt a policy of land conservation and intensive use, strictly adhering to the red line for cropland protection and avoiding excessive urban expansion. The regional land resource managers should focus more on the efficient use of urban land, optimizing the intensity of land development, and preventing further occupation of cropland or ecological land. Additionally, water resources are relatively scarce in these regions, especially in Beijing, which has long faced water shortages. The rational allocation and reuse of water resources should also be a priority in land management policies for these regions. It is very necessary to strengthen the development of water-saving cities and adjust the land use structure to address the increasingly pressing supply–demand conflicts regarding water resources in these regions. Moreover, Beijing and Tianjin in Region IV serve as the national political and cultural center and as important economic and port cities, respectively, the development goals of which are to leverage the role of national central cities and promote high-quality economic development. Therefore, the land management policies in this region should align with

these dominant functions, focusing more on optimizing the spatial layout of land resources and utilizing the limited land resources efficiently. Meanwhile, land management policies in this region should strictly limit large-scale industrial development and disorderly urban sprawl and reduce the occupation of ecological resources so as to maintain a balance between ecological and economic development.

## 5. Conclusions

Accurate revelation of the up-to-date characteristics of land use change across various functional zones, rather than administrative units, can lay a better foundation for formulating more scientific and reasonable land management policies to promote regional sustainable development. This study revealed the characteristics of land use change in seven functional zones of the Beijing–Tianjin–Hebei region during 1985–2022 based on the latest land use data and planning information, with the land use dynamic degree, transfer matrix, and comprehensive index of land use intensity. The major conclusions were drawn as follows: (1) Dominant land use types included cropland, forest land, grassland, and built-up land, generally with significant decreases in cropland and grassland and noticeable increases in built-up land and forest land in most functional zones, except Region I, where grassland increased significantly. (2) The single land use dynamics of built-up land and forest land were generally above 2.00% and 0.40%, respectively, while those of grassland and cropland were generally below zero in most functional zones. The comprehensive land use dynamics was 0.38% on average in the study area, but it was very high in Regions IV, I, and III, peaking above 0.70%. (3) There was remarkable conversion from cropland to forest land and grassland and from grassland to forest land in Region I. Meanwhile, there was mainly conversion from cropland to forest land and built-up land and from grassland to forest land in Regions II and VII, and there was dominantly conversion from cropland to built-up land in Regions III, IV, V, and VI. (4) The land use degree was relatively low in Regions I, II, and VII and much higher in Regions IV, V, and VI, declining only in Region I and increasing in other regions, increasing slowly from 267.28 in 1985 to 274.17 in 2022, on average. These findings accurately revealed long-term and latest characteristics of land use change across various functional zones of the Beijing–Tianjin–Hebei region, which can lay a firm foundation for formulating more sound and targeted land management policies.

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**Data Availability Statement:** The raw data supporting the conclusions of this article will be made available by the authors on request.

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