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The Impact of Desertification Dynamics on Regional Ecosystem Services: A Case Study of Inner Mongolia (China)

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Abstract

As one of the most important ecosystems of our planet, desert and desertified land have provided critical ecosystem services to support inhabitants of dry lands, and the desertification dynamics would have greatly impact on regional ecosystem services and economical-social development. In this study, the desertification dynamics in Inner Mongolia, China, and its impact on regional ecosystem services were analyzed by combining multisource data, GIS, and sensitivity analysis method. The results showed that the total ecosystem service value (ESV) decreased by 67.16 billion yuan from 1981 to 2010, and desertification dynamics had moderate linear correlation with ESV, which caused 23.7% decrease of ESV. The impacts of desertification dynamics on the change of ESV in different subregions had spatial heterogeneity, which had promoting effects in southwest of Inner Mongolia and reverse effects in northeast subregions. The sensitivity of ESV to desertification dynamics in different subregions also had obvious differences, and subregions with higher vegetation coverage always showed larger SAF (sensitivity coefficient). Different measures, such as reasonably utilizing water and soil resources, adopting water-saving technology, adjusting the industry structure, and developing the ecological industry, should be adopted by the government to control desertification and promote the ecosystem services.

Keywords: desertification, ecosystem service, impact, sensitivity, Inner Mongolia

1. Introduction

Desertification is land degradation in arid, semiarid, and dry subhumid areas resulting from various factors, including climatic variations and human activities [1, 2]. Desertification has

been treated as one of the most serious social-economic-environmental issues in our world, the total area affected by desertification reaches 6–12 million km^2, and about 1–6% of inhabitants of dry land live in desertified area [3]. The long-term intensive use and consume of land and vegetation resources, such as overgrazing, overcutting, excessive reclamation, and rapid urbanization, together with the climate change, made desertification expanded greatly in the globe over the past century, especially for the Sahel in Central and Northern Africa, Mediterranean region, Central and Western Asia, and North China [4–6]. For example, an analysis of a time series of remote sensing images between 1981 and 2003 revealed a persistently declining productivity throughout this period on over 20% of the global land, which had impact on 1.5 billion people [7].

As one of the most important ecosystems and land cover types in the planet, deserts and desertified land also provide some critical ecosystem services to support their inhabitants and economic-social development, including carbon fixation and oxygen release, hydrological regulation, soil conservation and sand fixation, biodiversity maintenance, and ecological tourism [8, 9], which create ecological and economic value [10, 11]. And, the desertification expansion would lead to the loss of ecosystem services and economy; research sponsored by the United Nations Environment Programme showed that the global economic losses caused by desertification and drought were as high as US 4.2×10^{10} each year, which was equivalent to all official aid to Africa in 2009 [12]. The reduction of ecosystem services and land production induced by desertification would have a great impact on the sustainable livelihoods of people living in rural community [13]; especially under the background of global warming and urbanization, the risk of land desertification and its potential impact on rural people would become higher and higher [14]. So, effectively control of desertification requires long-term systematic efforts aimed at restoring the functions of desert ecosystem services to realize the securing of both ecological and economic benefits. This will not only require the investment of large amounts of money and new technologies but also need the identification and effort of local people [15].

Over the past few decades, deserts and desertified land have changed greatly due to climate change and human activities, which had resulted in a significant alteration to these areas' global and regional ecosystem services [16–18]. In the process of desertification reversion, the dominant species, plant community structure, and landscape pattern change significantly; annuals gradually evolve into shrubs and perennial herbs, and the species richness, vegetation coverage, and landscape heterogeneity increase; and the soil sand content decreases, as well [19, 20]. All these changes might lead to the enhancement of ecosystem services. For example, a previous study in Yuyang District, Shaanxi Province, China, showed that the Project of Returning Farmland to Forest and other ecological measures had led to an increase in the regional sand stabilization function value of 5.64×10^6 yuan per year from 1988 to 2003 [21]. However, in the process of desertification expansion, vegetation is destroyed, and more soils are exposed to the air, which will increase the risk of wind erosion and make sand hill active, and then lead to the decrease of ecosystem services, especially for the sand fixation function and service. Research conducted by Ben Mariem and Chaieb had shown that the suitable habitat for alfa grass in Tunisia had increased greatly with the increase in greenhouse gas, which would lead the reduction of ecosystem services provided by dry lands [22]. So, scholars

have gained that a more consistent understanding of that increasing vegetation coverage can provide an effective measure to improve the ecosystem services in dry land [23].

Identifying and measuring the impact of desertification dynamics on regional ecosystem services is an effective way to assess the costs and benefits to the environment and support sustainable land management decisions in the rural community [24]. Accounting the ecosystem service value (ESV) is useful to analyze the impact of land use and land cover change [25, 26], including desertification dynamics, on regional ecosystem services. For example, Costanza et al. [27] and Daily et al. [28] estimated the global ESV by using a market valuation method, which made it possible to quantitatively analyze and compare the change in the ecosystem services. Ouyang et al. [29] assessed the value of terrestrial ecosystem services in China, including desert ecosystems. Xie et al. [30, 31] established and improved a service value table for desert ecosystems, which had important guiding significance for later studies in China. Yirsaw et al. [32] had analyzed the effect of temporal land use/land cover changes on ecosystem services in coastal area of China. However, these studies always underestimated the importance of the ecosystem services provided by deserts and desertified land, and less attention has been paid to the impact of desertification dynamics on the regional ecosystem services, which might lead to a misunderstanding of the effect of desertification control and sustainable land management in rural community.

China is one of the countries that is seriously affected by desertification in the world. According to the fifth desertification survey statistics of the State Forestry Administration of the People's Republic of China, the desertified area in China reached 2,611,600 km^2 in 2014, which accounted for 27.20% of the country's total land area [33]. Inner Mongolia autonomous region (hereinafter referred to as Inner Mongolia) is a representative ecologically fragile area in North China and seriously affected by desertification. Combating desertification and promoting the ecosystem services in this region are playing a critical role in guaranteeing the ecological security of North China. Although a great deal of ecological protect projects and polices, such as Three-North Shelterbelt Project, Beijing-Tianjin Sandstorm Source Treatment Project, Grain for Green Project [34, 35], no grazing policy [36, 37], have been carried out in recent years, extensive human activities such as mining and rapid urbanization still have a great impact on the vegetation cover and desertification [38, 39]. These factors coupled with climate change have generated significant changes in the desertification and ecosystem services of Inner Mongolia. So, it is necessary and meaningful to investigate the desertification dynamics and assess their impact on regional ecosystem services, which can provide support for policy-makers and land managers involved in desertification control and ecology rehabilitation in arid areas.

2. Materials and methods

2.1. Study area

Inner Mongolia lies between 37°24′N–53°23′N and 97°12′E–126°04′E in North China and includes a total of 88 counties or banners (hereinafter referred to as counties; **Figure 1**).
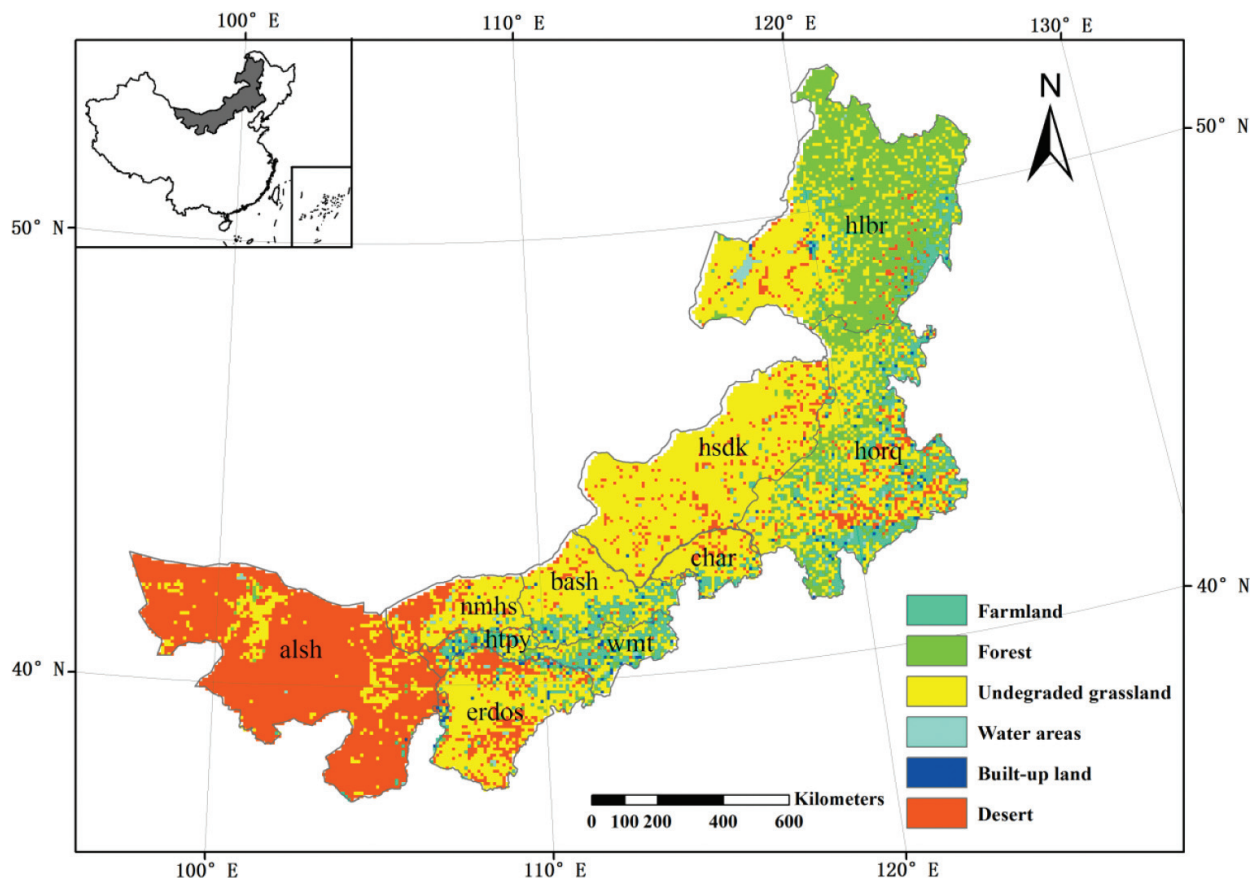
Figure 1. The area of study.

The study area covered approximately 1.18×10^6 km^2 or 12.3% of the country's total area. The temperate zone continental monsoon climate has an average temperature of 0–8°C and an annual total precipitation of 50–450 mm that progressively decreased from east to west. The region receives an average annual of 2850 h of sunshine and stands at an average elevation of 1000 m. The soils are mostly brown desert, chestnut, and sandy soils. Gales occur on 10–40 days annually, mainly in spring, and 5–20 days with sandstorms. Influenced by climatic factors (such as sandstorms, temperature, precipitation, etc.) and unsustainable human activities (such as grassland reclamation, abandonment of cultivated land, etc.), desertification become a serious problem in this region. To facilitate statistical and comparative analyses, the study area was divided into 10 subregions according to the climate characteristics and natural geography [40], including the Hulun Buir grassland (hlbr), Horqin grassland (horq), Hunshandake sandy land (hsdk), Chahar grassland (char), Bashang area (bash), Wumeng Qianshan and Tumote plain (wmt), Houshan region in Inner Mongolia (nmhs), Hetao plain (htpy), Erdos grassland (erdos), and Alashan plateau (alsh).

2.2. Data collection and process

The data used in this study included NDVI (normalized difference vegetation index) data, land use data, high-resolution remote sensing images, and other auxiliary data. NDVI used in this

study was the Global Inventory Modeling and Mapping Studies (NDVI3g) dataset, with these data obtained from the National Aeronautics and Space Administration. The time resolution of this dataset was half a month with a spatial resolution of 8 km and the time range of 1981–2010. This dataset has been preprocessed by geometric correction and graphic enhancement to ensure data quality. The land use data in 1980s and 2010s with an accuracy of 1 km was derived from the Chinese Academy of Sciences Resource and Environmental Data Center, and the national county-level administrative maps used to generate the boundary data of the study area came from the National Geomatics Center of China. The Landsat TM/ETM images covering the study area came from the United States Geological Survey (USGS) and Google Earth. Auxiliary data, such as meteorological and statistical information, were also collected from the National Meteorological Information Center and the national and regional Statistical Yearbooks. To facilitate spatial analysis and comparison, all the grid and vector data used in this study were resampled or converted into grid data with an 8 km resolution.

2.3. Methods

2.3.1. Land classification and desertification monitoring

To analyze the impacts of desertification on the regional ecosystem services, the land use and land cover of the study area were classified into two categories: deserts and desertified land and non-desertified land. According to the land use type, non-desertified land was further divided into farmland, forest, undegraded grassland, built-up land, and water areas. The deserts and desertified land were further divided into regions of low, medium, high, and severe desertification based on the degree of desertification. The NDVI data, land use map, and high-resolution images were used to classify the land use and land cover types. Our procedure was as follows: (1) We extracted non-desertified lands. A 1:100,000 land use map was used to identify farmland, forest, built-up land, and water areas. By combining high-resolution remote sensing maps from Google Earth and our field investigation, 100 sample points for each subregion were selected for undegraded grassland; the NDVI threshold value system was then used to extract the undegraded grassland. (2) We extracted deserts and desertified land with different grades. The method of undegraded grassland extraction involved the selection of 100 sample points for each subregion to identify the desert regions. Then, the NDVI threshold desertification value system for the lands (low, medium, high, and severe) was established by equal interval dividing the NDVI value between the deserts and undegraded grassland. To avoid classification errors caused by short-term climate fluctuations, the average NDVI values for nearly 3 years were used to extract the information about deserts and desertified land in 1981 and 2010. In this study, a visual inspection was conducted to correct the classification errors and adjust the threshold values. Fifty checkpoints were randomly selected in every subregion to verify the results, and the overall classification accuracy was more than 90%.

2.3.2. Assessing the impact of desertification dynamics on ecosystem services

In this study, the ESV was used as a proxy to measure the impact of desertification dynamics on regional ecosystem services. The ESV per unit area of each land category was compared

with different biomes and assigned based on the results derived by Xie et al. [31], who had estimated the equivalent weight factors and modified the ESV coefficient per hectare of terrestrial ecosystems in China. To quantitatively assess the impact of land with different desertification degrees on the regional ESV, the ESV for the low, medium, high, and severely desertified lands was assigned by the use of the equal interval grading weight factor between the ESV of the deserts and undegraded grassland:

$$ESV = \sum_{i=1}^{n} P_{ij} \times A_i \qquad (1)$$

where ESV is the total ecosystem service value of one region (10,000 yuan·km^{-2}·a^{-1}), P_{ij} is the adjusted ESV per unit area of land use and land cover type i (10,000 yuan·km^{-2}·a^{-1}), and A_{ij} is the area of land use and land cover type i (km^2).

We took into consideration the differences in the ESV provided by the same type of land use and land cover in different regions and introduced an adjusting factor in this study by biomass because the ESV always has a robust positive relationship with the biomass [41]:

$$P_{ij} = (b_j/B)P_i \qquad (2)$$

where B_j is the biomass of the land use and land cover type i, which was replaced by the NDVI in this study. B is the average biomass of the land use and land cover type i in China, which was also calculated by NDVI; and P_i is basically the ESV per unit area of land use and land cover type i in China (10,000 yuan·km^{-2}·a^{-1}), which is shown in **Table 1**.

2.3.3. Sensitivity analysis

In this study, the sensitivity coefficient was conducted to assess the changing degrees of the regional ESV that was caused by desertification. The sensitivity coefficient (SAF) measured the sensitivity degree by comparing the changes in the ESV of the whole region to the deserts and desertified land from 1981 to 2010:

$$SAF = \frac{(VC' - VC)/VC}{(S' - S)/S} \qquad (3)$$

where SAF is the sensitivity coefficient and higher values of $|SAF|$ indicate greater changes in the regional ESV caused by desertification; VC' is the regional ESV in 2010; VC is the regional ESV in 1981; S' is the ESV of the deserts and desertified lands in 2010; and S is the ESV of the deserts and desertified lands in 1981.

|	Forest	Farmland	Water areas	Low desertification	Medium desertification	High desertification	Severe desertification	Desert
Total	126.29	35.48	203.67	47.17	39.31	26.21	18.34	6.24

Table 1. The ESV per unit area of different land types in Inner Mongolia (million yuan/km^2/a).

3. Results

3.1. The desertification dynamic in Inner Mongolia from 1981 to 2010

From 1981 to 2010, the area of deserts and desertified land in Inner Mongolia expanded from 555.3 km^2 in 1981 to 624.5 km^2 in 2010. Except for a decrease of 28,000 km^2 in deserts, the area of land with low, medium, high, and severe desertification all showed different increases. The largest increment is caused by medium desertification, which increased 48.77% over 1981. Reversion and expansion between lands with different desertification degrees and between desertified and non-desertified lands are equally significant, which showed a significant spatial heterogeneity. In the 30 years, the area of desertification reversion in Inner Mongolia was 170,900 km^2, with an expansion area of 204,300 km^2 (**Figure 2**).

The area of desertification reversion was mainly distributed in erdos, alsh, bash, and other areas in southwest Inner Mongolia. Among them, the area of desertification reversion in erdos accounted for 8.71% of the desertified land area of Inner Mongolia. The area of desertification reversion in alsh and bash also reached 8.33 and 5.1% of the total desertification area, respectively. The reversal area among different degrees of desertification accounted for 17.98% of the total desertification area. The reversal area from deserts and desertified land to non-desertified
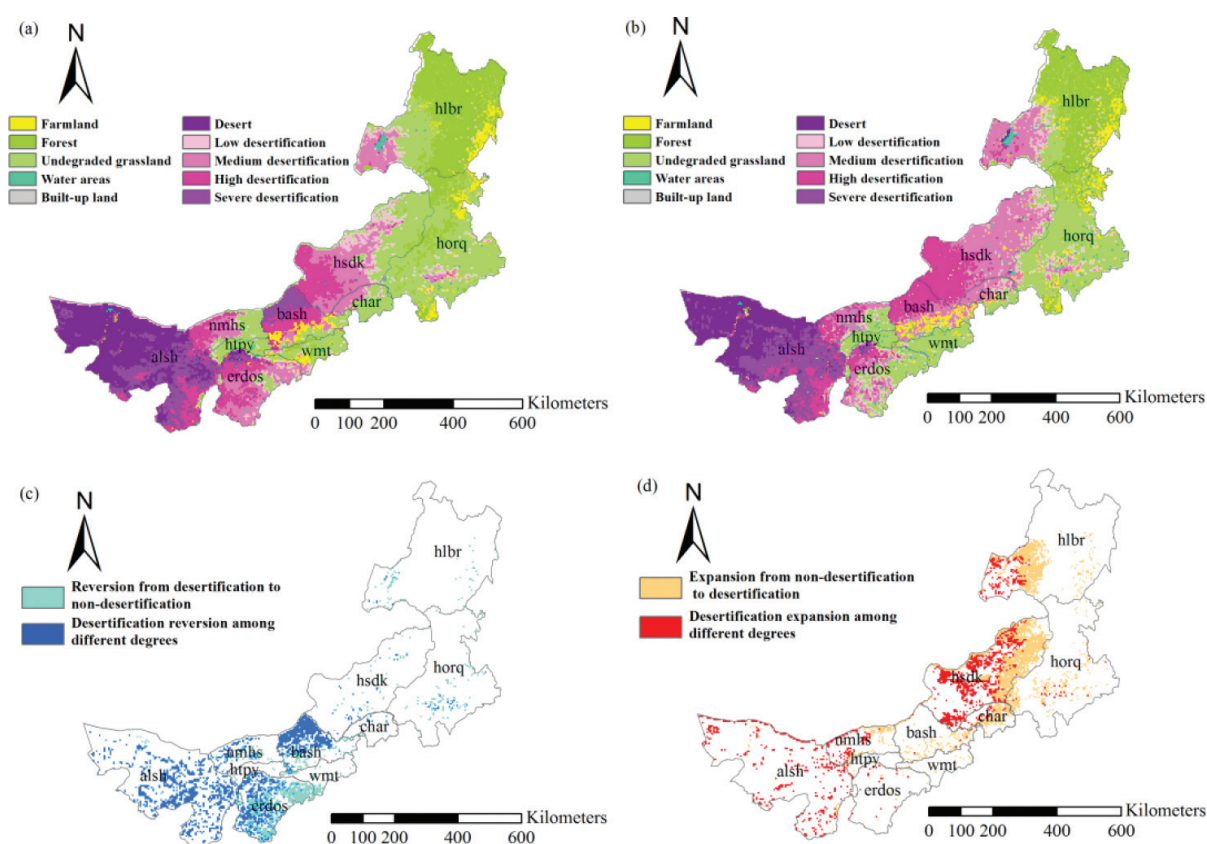
Figure 2. Land use and desertification change in Inner Mongolia autonomous region from 1980s to 2010s. (a) Land use and desertification map in 1981, (b) land use and desertification map in 2010, (c) desertification reversion and (d) desertification expansion.

lands accounts for 9.38% of total desertification area, which was dominated by the reversion to undegraded grassland. The expansion of desertification mainly occurred in central-northern Inner Mongolia, such as southwestern hlbr, hsdk, and char. The desertification expansion in hsdk accounted for the largest proportion of total desertification area, reaching 13.76%. The expansion area among differing degrees of desertification accounted for 12.28% of the whole deserts and desertified land, and the area of land that expanded from non-desertified lands to deserts and desertified land was nearly twice as much as the area of desertification expansion among different degrees, which was mainly attributed to the expansion from undegraded grassland to desertification.

3.2. Changes of the ESV in Inner Mongolia from 1981 to 2010

The total ESV of Inner Mongolia decreased 67.16 billion yuan from 1981 to 2010 (**Table 2**), which was equivalent to 5.74% of Inner Mongolia's GDP in 2010. For different land use types, the ESV of forest and undegraded grassland decreased significantly, and the ratio of the total value of the two ecosystems dropped from 52.02% in 1981 to 44.18% in 2010. In addition, the ESV of desert also showed a downward trend with a rate of change of -19.12%. The increase of ESV mainly occurred in farmland and desertified land, and the ESV of desertified land had increased 19.97 billion yuan.

The ESV in Inner Mongolia had illustrated a great spatial heterogeneity (**Figure 3**); the ESV in eastern and southern part was higher than western and northern part. The high value area (500–110 million yuan) was mainly located in hlbr, and the unit grid (64 km^2) ESV reached more than 50 million yuan, while the unit grid ESV in alsh located in the western of Inner Mongolia was less than 5 million yuan, which was mainly attributed to the zonal distribution of vegetation. Compared with 1981, the ESV in northeastern hsdk and central hlbr had

Land type	ESV		The ecological value change	Rate (%)
	1981	2010		
Forest	304.97	229.35	−75.62	−2.48
Undegraded grassland	181.65	160.28	−21.37	−1.18
Farmland	15.38	18.25	2.88	1.87
Water areas	7.80	15.19	7.40	9.49
Desert	2.19	1.77	−0.42	−1.91
Low desertification	22.69	23.91	1.22	0.54
Medium desertification	34.42	51.21	16.79	4.88
High desertification	12.54	14.12	1.58	1.26
Severe desertification	4.65	5.03	0.38	0.82
Total	586.28	519.12	−67.16	−1.15

Table 2. The total regional ESV and its change in Inner Mongolia between 1981 and 2010 (billion yuan).
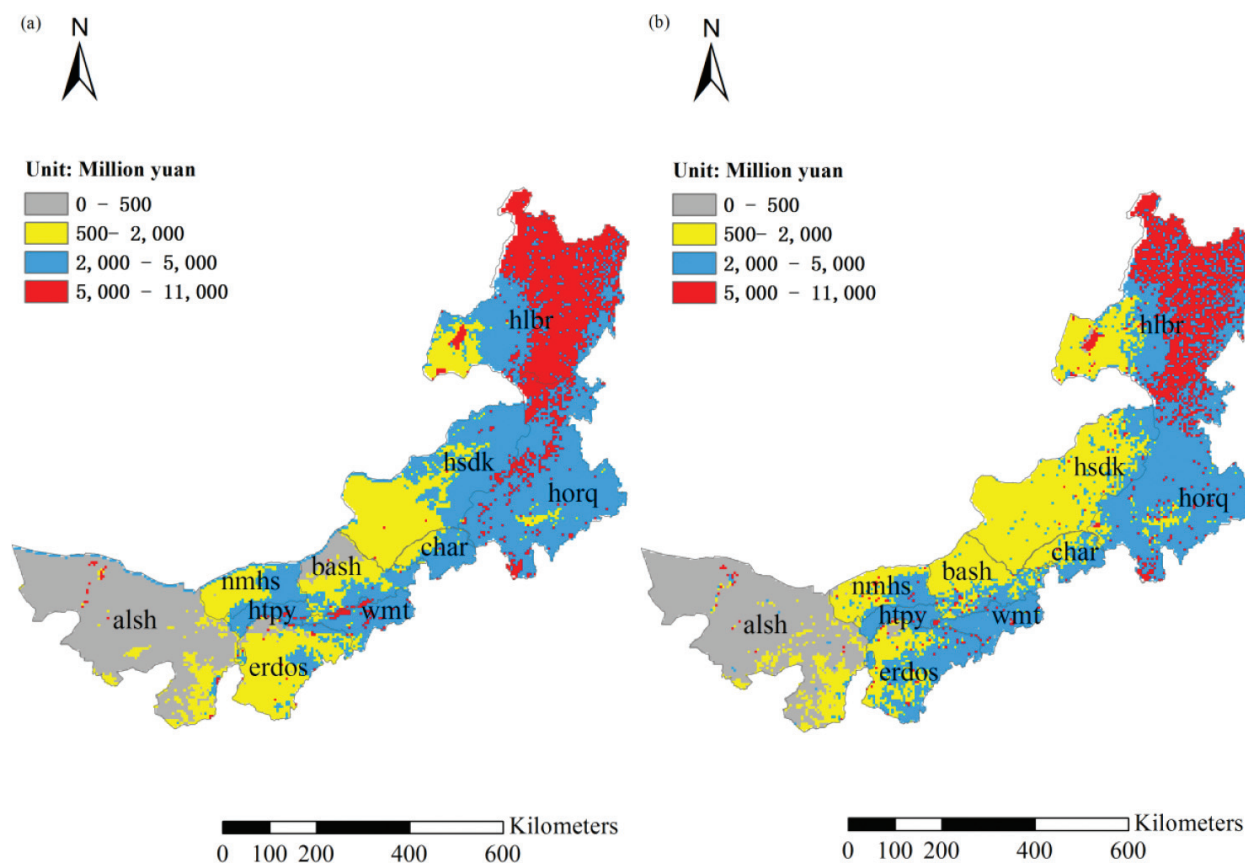
Figure 3. Spatial distribution of unit grid ESV in Inner Mongolia in 1981 and 2010. (a) 1981 and (b) 2010.

decreased in 2010, while the ESV in northeastern erdos had increased, and other regions did not change obviously.

3.3. The impact of desertification dynamics on regional ESV in Inner Mongolia

From 1981 to 2010, the desertification dynamic (reversion and expansion) in Inner Mongolia had a great impact on the whole regional ESV, which had led to a loss of 15.89 billion yuan of the ESV (**Tables 3** and **4**), accounting for 23.7% of the total loss. The Pearson correlation coefficient between the change of ESV and the change of ESV caused by desertification reached 0.63 ($p < 0.05$), which showed a moderate linear correlation between them.

The increment of the ESV caused by desertification reversion was 32.43 billion yuan, which accounted for 6.25% of the total ESV in 2010. The increment of the ESV caused by desertification reversion among different degrees reached 10.05 billion yuan, and the reversion of high desertification had led to an increment of 4.17 billion yuan. The increment of the ESV caused by reversion from deserts and desertified land to non-desertified lands was about 2.2 times as much as the increment of the ESV caused by reversion between lands with different desertification degrees, and the reversion from deserts and desertified land to undegraded grassland alone increased the ESV by 10.65 billion yuan. In terms of desertification expansion, expansion between lands with different desertification degrees had led to 10.17 billion yuan loss of ESV.

Value	Desertification reversion among different degrees	Reversion from desertification to non-desertification			
Change type		Forest	Undegraded grassland	Farmland	Water areas
Low desertification	—	2.20	1.72	0.05	0.83
Medium desertification	1.78	1.51	6.62	0.36	2.91
High desertification	4.17	0.82	2.13	0.51	0.80
Severe desertification	1.82	0.11	0.12	0.04	0.30
Desert	2.28	1.14	0.06	0	0.16

Table 3. The impact of desertification reversion on regional ESV (billion yuan).

Value	Desertification expansion among different degrees	Expansion from non-desertification to desertification			
Change type		Forest	Undegraded grassland	Farmland	Water areas
Low desertification	−6.32	−5.67	−4.40	−0.06	−0.28
Medium desertification	−3.00	−0.94	−21.24	−0.47	−0.39
High desertification	−0.53	0	−1.53	−0.05	−0.36
Severe desertification	−0.32	−0.32	−0.38	0	−0.30
Desert	—	−0.11	−0.13	−0.02	−1.50

Table 4. The impact of desertification expansion on regional ESV (billion yuan).

Among them, the impact of low and medium desertification expansion was more obvious. The area of expansion from non-desertified lands to deserts and desertified land was 127,700 km^2, which had led to 38.15 billion yuan loss of ESV, and was mainly induced by the expansion from forest and undegraded grassland to low and medium desertification.

3.4. Impact of desertification dynamics on regional ESV in different subregions

The impact of desertification dynamics on regional ESV at the subregion level showed a significant spatial heterogeneity. From 1981 to 2010, the ESV in bash, htpy, and erdos was increased, and the desertification dynamics played a promoting role in this increment, which meant the increment of ESV of deserts and desertified land led to the increase of regional ESV. The ESV in hlbr, hsdk, char, and horq showed a decreasing trend, and the desertification dynamics also showed a promoting effect, which was mainly attributed desertification expansion in these subregions. However, the desertification dynamics in wmt, nmhs, and alsh had an opposite effect on the change of regional ESV.

Subregion	The total ESV change (billion yuan)	ESV change caused by desertification dynamics (billion yuan)	Sensitivity coefficient (SAF)
hlbr	−39.38	−10.39	8.91E−8
hsdk	−18.19	−17.21	2.38
char	−2.26	−2.08	4.21
horq	−17.35	−41.77	74.53
bash	1.77	2.50	4.52
wmt	−1.56	1.00	−9.83
htpy	0..07	0.28	53.15
nmhs	0.20	−0.05	−0.57
erdos	12.18	12.02	1.36
alsh	−0.13	0.60	−6.12

Table 5. Sensitivity analysis of regional ESV to desertification dynamics.

In this study, sensitivity coefficient was introduced to quantitatively analyze the sensitivity of the regional ESV change to desertification dynamics, and the results of the sensitivity degree showed a great spatial heterogeneity (**Table 5**). The ESV in horq and htpy was very sensitive to desertification dynamics, and the sensitivity coefficient reached 74.53 and 53.15, respectively. However, both hlbr and nmhs showed the same or opposite sensitivities, the coefficients all hovered around 0, and the sensitivity was relatively small.

4. Discussion

As one of the most important land degradation types in dry land, desertification dynamics can bring a great impact on regional ecosystem service supply and sustainable livelihoods, especially for the people living in rural area. According to the Millennium Ecosystem Assessment (MEA), livelihood activities in dry land tend to be more dependent on available ecosystem services than elsewhere [42]. In order to enhance the ecosystem services and sustainable development in dry land, UNCCD had launched a policy strategy called "Zero Net Land Degradation" (ZNLD) in 2012, aiming to prevent the degradation of productive land and restore already degraded land by sustainable land management. To achieve these goals, we need to investigate the impact of desertification dynamics on regional ecosystem services at regional scale and identify the sensitive area to support the policy-making.

Due to the location and various driving factors, Inner Mongolia of China is a perfect place to study desertification dynamics and its impact on regional ecosystem services. According to our study, impacted by both climate change and human activities, desertification in Inner Mongolia had changed dramatically over the past three decades. Due to the implementation process of the "Three North" Shelterbelt Project, the Beijing-Tianjin sandstorm source project,

and the Natural Forest Protection, the coverage of vegetation was increased, and some areas showed obvious desertification reversion [43], which made it possible to increase the ESV. In the same period, intensive human activities, such as coal mining, oil and gas drilling, road, subway, and pipeline laying, had promoted the economic development in rural areas and pastoral areas as well as destroy the vegetation in ecologically fragile regions with abundant resources; land desertification problem was more prominent [44], resulting in ESV loss. All factors mentioned above made the impact of desertification dynamics on regional ESV, which showed a great spatial heterogeneity.

The further investigation based on the sensitive analysis results showed that the desertification reversion in erdos and alsh had play a promoting role in the increment of regional ESV, which was mainly attributed to the ecological projects and policies implementation and ecology-based industry development. Taking alsh as an example, by developing the farming of *Haloxylon-Cistanche*, two genera of useful plants, the yield of *Cistanche* increased from 200 to 800–1000 tons per year in Inner Mongolia, which not only increased the income of farmers but also achieved the goal of combating desertification [45]. However, the ESV in nmhs and horq showed a significant decreasing trend, especially for horq, whose sensitive coefficient reached 74.53, and these regions should be the focus of desertification control in the future. For the ESV decrement areas which are less sensitive such as hlbr, more attention should be paid to protect and prevent damage. To avoid the reduction of forest and undegraded grassland area and quality decline, different measures, such as soil and water management and rational exploitation, improve the quality of population, and delineation of "ecological red line," should be implemented to ensure the regional ecological security.

The impact of desertification dynamics on regional ecosystem services was carried out by monetizing the value of different ecosystems, including deserts and desertified land. According to the equal interval principle, five desertification grades were divided. The low and medium desertified areas might overlap the grassland with a certain degree of desertification. Thus, compared with other research results [46, 47], the area and ESV of deserts and desertified land were higher, and the area and ESV of undegraded grassland were lower. However, the land classifications in this study could be used to objectively analyze the impact of different processes of desertification on regional ecosystem service change. In the future, data of climate change and human activities would be involved to quantify the mechanisms of the impact of desertification dynamics. Besides, the linkage of ecosystem service change and sustainable livelihoods of rural community should be further investigated, and the specific measures and policies for how to enhance the adaptive ability and resilience of rural community should be studied in the future.

5. Conclusion

From 1981 to 2010, the desertification dynamics in Inner Mongolia were obvious. The area of the lands that experienced desertification reversion was 170,900 km^2, which was mainly distributed in erdos, alsh, and other sand areas in the southwest. The area of the lands experiencing desertification expansion was 204,300 km^2, and these lands were mainly located in hsdk and

other north-central sand areas. There was a significant spatial heterogeneity in the desertification reversion and expansion, and the main changes in the types of desertification were between adjacent desertification degrees.

Over the past 30 years, the ESV in the Inner Mongolia has decreased by 67.16 billion yuan. Compared with 1981, the ESV in the northeast hsdk, central hlbr decreased, and the ESV in the eastern erdos increased. Desertification dynamics had a great impact on regional ESV in Inner Mongolia, and the ESV decrement caused by desertification dynamics reached 15.89 billion yuan, accounting for 23.7% of the total value loss.

Desertification reversion and expansion on the ESV showed a spatial heterogeneity. The desertification dynamics had promoted the ESV change in bash and hlbr but played an opposite role in wmt and other places. The sensitivity of ESV to desertification was also different. Horq and htpy were more sensitive than other sub-regions, and the sensitivity of them were higher than 50. Hlbr and nmhs was less sensitive. To enhance economic development and the ecological service supply, "win-win" measures should be used for subregions with different sensitivities.

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