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Article

Analysis of Multi-Scale Changes in Arable Land and Scale Effects of the Driving Factors in the Loess Areas in Northern Shaanxi, China

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Abstract: In this study, statistical data on the national economic and social development, including the year-end actual area of arable land, the crop yield per unit area and 10 factors, were obtained for the period between 1980 and 2010 and used to analyze the factors driving changes in the arable land of the Loess Plateau in northern Shaanxi, China. The following areas of arable land, which represent different spatial scales, were investigated: the Baota District, the city of Yan'an, and the Northern Shaanxi region. The scale effects of the factors driving the changes to the arable land were analyzed using a canonical correlation analysis and a principal component analysis. Because it was difficult to quantify the impact of the national government policies on the arable land changes, the contributions of the national government policies to the changes in arable land were analyzed qualitatively. The primary conclusions of the study were as follows: between 1980 and 2010, the arable land area decreased. The trends of the year-end actual arable land proportion of the total area in the northern Shaanxi region and Yan'an City were broadly consistent, whereas the proportion in the Baota District had no obvious similarity with the northern Shaanxi region and Yan'an City. Remarkably different factors were shown to influence the changes in the arable land at different scales. Environmental factors exerted a greater effect for smaller scale arable land areas (the Baota District). The effect of socio-economic development was a major driving factor for the changes in the arable land area at the city and regional scales. At smaller scales, population change, urbanization and socio-economic development affected the crop yield per unit area either directly or indirectly. Socio-economic development and the modernization of agricultural technology had a greater effect on the crop yield per unit area at the large-scales. Furthermore, the qualitative analysis indicated that government policies had a more significant impact on the large-scale arable land areas.

Keywords: scale effect; driving factors; Loess Plateau in northern Shaanxi; arable land; quantitative; qualitative

1. Introduction

Land use is a central component of biophysical, social, and economic systems acting across various scales [1]. Land-use change may lead to a reduction in biodiversity, soil, and water pollution through the use of fertilizers and pesticides, soil sealing and compaction, and altered hydrological, nutrient and atmospheric cycles, and it has important impacts on the environment [2]. Moreover, the analysis of arable land changes and the factors influencing these changes are popular topics in the investigation of land use change. Currently, in China and other countries, rural areas are commonly used to investigate the changes in arable land and the corresponding factors driving these changes. Current research has focused primarily on analyzing the quantitative changes occurring in a single spatial region over a long time period [3–6], whereas the analysis of changes in arable land and the scale effects of the corresponding driving factors are also important. Multi-scale analyses are currently a frontier of physical geography research, and apparent scale characteristics have been observed in the relationship between land changes and their driving factors [7,8]. When undetected, there may some errors in extrapolation from one region to another, so identifying the scale effect of the driving factors is required to investigate the cause of the changes in arable land [9,10]. Consequently, multi-scale studies of arable land changes and the underlying driving factors have a positive scientific significance for elucidating the mechanism of change in arable lands and developing targeted measures for arable land protection.

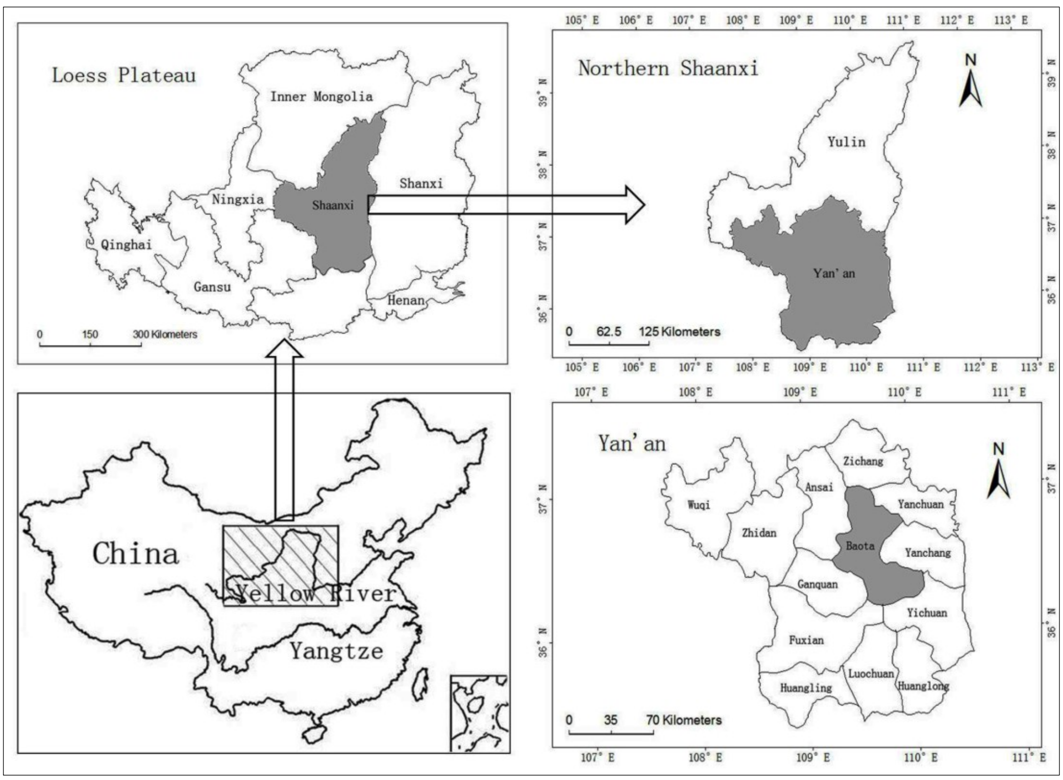
The Loess Plateau in the northern Shaanxi Province has long been subjected to the traditional restraints of monotonous agricultural operations and broad and extensive cultivation with meager yields, which has led to an ineffective and irrational use of land resources manifested in the widespread phenomenon of excessive land reclamation. Despite its vastness, the arable land in this area is mostly hillside and of poor quality, which results in the people of the region living in poverty with restricted access to sustainable social, economic, and environmental development. Using the Loess Plateau in northern Shaanxi as the subject of this study, the changes in arable lands in three regions of different scales- the Baota District, the city of Yan'an, and the northern Shaanxi region- were characterized, and the scale effects of the driving factors were investigated. This study was undertaken to supplement the studies examining the scale effect and to provide a scientific basis to formulate targeted protection measures for arable land in these areas.

2. Materials and Methods

2.1. Study Area

We selected the northern Shaanxi region, the city of Yan'an, and the Baota District as our study area (Figure 1).The northern Shaanxi region is located in the central area of the Loess Plateau in China and includes the cities of Yulin and Yan'an in the Shaanxi Province. The Loess Plateau in northern Shaanxi was formed through water etching and soil erosion in the Cenozoic laterite, and a thick layer of loess covers the top of the Mesozoic bedrock-constituted paleotopographic structure. The basic topographic forms in the Loess Plateau are loess tablelands, ridges, hills, and gullies. During the study period, the northern Shaanxi region was an economically impoverished region of the Shaanxi Province. Overall, its economic level was unbalanced, and the gap between the rich and poor was large. The city of Yan'an is located in the southern half of the northern Shaanxi and has a continental plateau monsoon climate. The Yan'an City, which has a vast territory, is rich in natural resources and is the heart of the Golden Triangle for economic cooperation zones in the northern Shaanxi region. The economic development of Yan'an City has been rapid. The municipal government of Yan'an is located in the Baota District, which is in the hill and gully region of the central Loess Plateau in northern Shaanxi and exhibits a terrain that slopes from the northwest to southeast. The major landform consists of ridge-shaped loess hills. The Baota District has a warm temperate climate characterized by frequent temperature changes and large temperature differences. As the political, economic and cultural center of Yan'an City, the Baota District is the forefront of development in the western region and has a development advantage of connecting the east and west.

Figure 1. Study area of three different scales (the northern Shaanxi region, the city of Yan'an, and the Baota District).



2.2. Data

Data obtained between 1980 and 2010 were used to analyze the changes in the arable land of the Loess Plateau of northern Shaanxi and to investigate the scale effect of the driving factors. The arable land-related data and statistical data for each year were collected from the following sources: the "Statistical Yearbook of the Socio-economic aspects of Baota District", "Statistical Yearbook of National Socio-economic Development of Yan'an City" and "Statistical Yearbook of National Socio-economic Development of Yulin City", which are annual statistical data records that comprehensively reflect the economic and social development in the Baota District, Yan'an City and Yulin City. These books contain a large amount of annual statistical data of the city, county and district, which are under the jurisdiction of the study area and published by China Statistics Press, public offering.

2.3. Selected Index Factors

For this study, we mainly analyzed rice, corn, millet, beans, potatoes, oil and other local crops. The arable land area was used as the characteristic index for the quantity of arable land. Because the yield is a direct reflection of changes in the quality of arable land, the crop yield per unit area was used as the characteristic index for the quality of the arable land [11]. The year-end actual area of arable land (Y_1) and crop yield per unit area (Y_2) between 1980 and 2010 were selected as the dependent variables for the principal component analysis. The following ten index factors were selected as the independent variables: total population (X_1), agricultural population (X_2), non-agricultural population (X_3), local GDP (X_4), agricultural production (X_5), per capita net income of farmers (X_6), total power of agricultural machinery (X_7), agricultural consumption of chemical fertilizers (X_8), average annual temperature (X_9), and annual precipitation (X_{10}).

Land use change is driven by complex interactions of environmental and socio-economic factors [12]. So the factors driving the changes to the arable land can be analyzed from two main perspectives, the socio-economic and environmental aspects of the land. The selected factors can be organized into six categories.

(1) Population: Total population (X_1) has been selected to characterize the impact of population growth on the change in arable land.
(2) Urbanization: Urbanization is the process of concentrating the regional population into towns and cities. To characterize the degree of urbanization, agricultural population (X_2), non-agricultural population (X_3) was selected to measure the impact of urbanization on the arable land changes.
(3) Socio-economic development: Local GDP (X_4), agricultural production (X_5), and per capita net income of farmers (X_6) were selected as the indices to characterize the socio-economic developmental impact on the arable land changes.
(4) Modern technology in agriculture: Agricultural modernization is the process and means of transforming from traditional agriculture to modern agriculture. The total power of agricultural machinery (X_7) and agricultural consumption of chemical fertilizers (X_8) were selected as indicators of the modernization of agriculture technology.

(5) Environmental factors: The Loess Plateau is one of the areas facing the most serious soil erosion in China; the annual loss of arable land as a result of soil erosion has numerous causes. The selected average annual temperature (X_9) and annual precipitation (X_{10}) were two environmental factors used as indicators to reflect the impact of natural disasters on arable land changes.

(6) Agricultural policy: National policy changes often cause dramatic changes in arable land. We mainly analyzed the impact of the "Grain-for-Green" policy on arable land changes.

2.4. Methods

The rate of decline in arable land area was used to analyze the dynamic changes of arable land area. The rate of decline in arable land area can vividly illustrate the change in arable land area. The rate of decline in arable land area is calculated as follows:

$$d = \frac{(M_1 - M_2)}{M_1} \times 100\% \tag{1}$$

where d is the rate of decline in arable land area; M_1 is the arable land area at the end of last year; and M_2 is the arable land area at the end of this year. If the rate of decline in arable land area is negative, then there was an increase in the arable land area; otherwise, the arable land area decreased. Greater absolute negative values indicated that the year-end actual arable land area grew faster, and vice versa [13].

Changes in the quantity and quality of arable land resulted from the combined effects of environmental, socio-economic, and technical factors [14,15]. To quantitatively analyze the effect of each factor on the changes in arable land, a principal component analysis was adopted for the comprehensive analysis of the numerous original index factors of selected correlations, to generate a new set of index factors to replace the originals.

Kaiser-Meyer-Olkin (KMO) and Bartlett tests should be performed before the principal component analysis. The KMO statistic varies between 0 and 1, and Kaiser recommends a bare minimum of 0.5; values between 0.5 and 0.7 are mediocre, values between 0.7 and 0.8 are good, values between 0.8 and 0.9 are great and values above 0.9 are superb [16,17]. Bartlett's test actually tests whether the correlation matrix is sufficiently different from an identity matrix. A significance test (the value of Bartlett's test less than 0.05) indicated that the variables were sufficiently correlated to provide a reasonable basis for a principal component analysis [18].

During the principal component analysis, we extracted the eigenvalues of the factors for the contribution rate of the principal components and loading matrix of the principal components. Eigenvalues and contribution rates of the principal components are the basis for selecting the number of principal components. There are three criteria for determining the number of main components: (1) the eigenvalues are greater than 1; (2) the cumulative contribution rate of principal components is more than 80%; and (3) the point mutation of the eigenvalues. The loading matrix of the principal component refers to a loading matrix of the eigenvector matrix, and each column shows a correlation coefficient of each variable and the main component, which reflects the variable's importance to the main component [19].

A canonical correlation analysis is a statistical method employed to investigate relationships among two or more variable sets that each consist of at least two variables. The result is acceptable when the p-value is less than 0.05. The correlations between the principal components involved in the changes and properties of arable land were analyzed to determine the primary factors that affect the changes in arable land.

It was difficult to quantify the impact of the national government policies on the arable land changes. Therefore, in this study, the contribution of the national government policies to the changes in arable land were analyzed qualitatively for the Baota District, Yan'an, and the northern Shaanxi region (areas representing three different spatial scales, in increasing order of area).

3. Results and Discussion

3.1. Dynamic Changes and Scale Variability of Arable Land

Figures for year-end actual arable land proportion of the total area were used to clearly show the year-end actual area changes in arable land at different scales. As shown in Figure 2, the trends of the year-end actual arable land proportion of the total area in the northern Shaanxi region and Yan'an City were broadly consistent. Both could be divided into three stages: a stable period (between 1980 and 1998); a drastically decreasing period (between 1999 and 2003) in which the average decline rate in arable land of Yan'an City and the northern Shaanxi region were 9.8% and 6.2% respectively (Figure 3); and a third period (between 2004 and 2010) in which the trend of the year-end actual arable land proportion in Yan'an City was different from that in the northern Shaanxi region. The year-end actual arable land proportion of northern Shaanxi region was increased after a brief period of stability from 2003 to 2010, whereas that of Yan'an City was remained broadly stable after the reduction. However, the year-end actual arable land proportion of the Baota District had small changes from 1980 to 2010, which had no obvious similarity with the northern Shaanxi region and Yan'an City. Overall, the area of the arable land at the three different scales (the Baota District, the city of Yan'an, and the northern Shaanxi region) exhibited a decreasing trend from 1980 to 2010. Furthermore, the trends of the year-end actual arable land proportion of the total area in the northern Shaanxi region and Yan'an City were broadly consistent, whereas that in Baota District had no obvious similarity with the northern Shaanxi region and Yan'an City.

Figure 2. Comparison of the year-end actual area of arable land proportion of the total area.

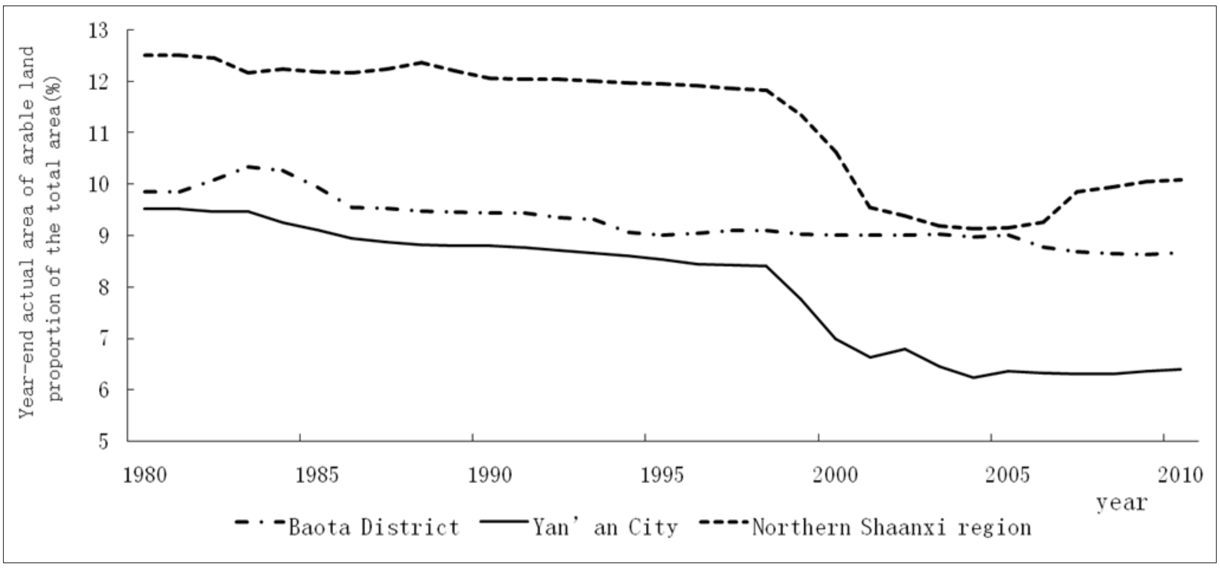


Figure 4 shows the complicated upward trend of the crop yield per unit area at the three scales. The minimum crop yield per unit area was 1728.98 kg/ha in 1997 in the Baota District, 1871.96 kg/ha in 1997 in Yan'an, and 883.25 kg/ha in 1987 in the northern Shaanxi region; the maximum crop yield per unit area was 3646.83 kg/ha in 1996, 3914.94 kg/ha in 2010, and 3055.63 kg/ha in 2010, respectively, for the three scales. The crop yield per unit area exhibited a complicated upward trend over the years within the individual regions, and significant changes were observed in the crop yields among the different regions. For each year from 1980 to 2001, crop yields per unit area were observed to be lowest at the largest spatial scale. Between 2002 and 2010, the crop yield per unit area in Yan'an exceeded that of the Baota District, whereas the crop yield per unit area of the Baota District was higher than that of the northern Shaanxi region (Figure 4).

Figure 3. Changes in the rate of decline in the year-end actual arable land area. (The negative values indicate that the year-end actual arable land area increased; greater absolute negative values indicated that the year-end actual arable land area grew faster, and vice versa.)

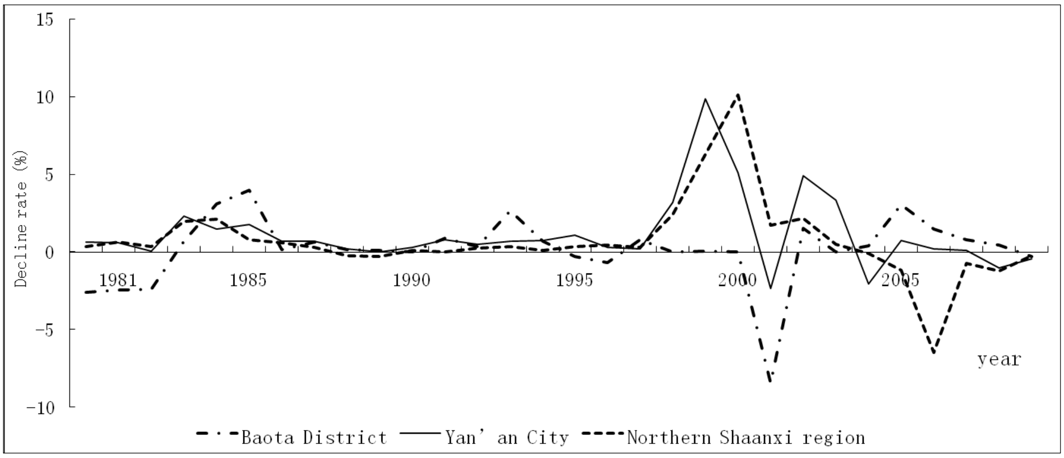
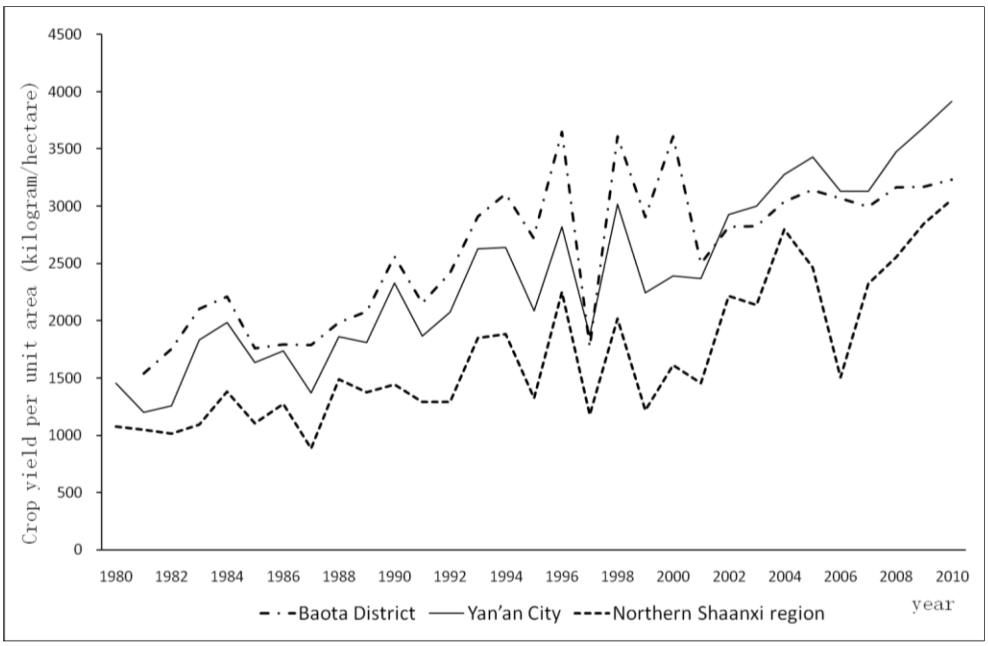


Figure 4. Comparison of changes in the crop yield per unit area.



Crop yields per unit area were affected by the combined effect of several factors, such as climate, agricultural machinery power, chemical fertilizer and labor inputs per unit area. Impact factors were different if the research scales were different, and the crop yields per unit area were different if the impact factors changed. In addition, considering the local conditions, the Baota District and Yan'an City were the economically developed regions of northern Shaanxi region. The agricultural modernization conditions of the Baota District and Yan'an City, such as the use of agricultural chemical fertilizer, agricultural machinery power and other conditions, were relatively better than other regions in northern Shaanxi. Therefore, the crop yields per unit area were usually observed to be lowest at the highest spatial scales.

3.2. Factors Driving the Changes in Arable Land Area and Their Scale Variability

3.2.1. Principal Component Analysis of the Factors Driving Arable Land Changes

The data were analyzed using SPSS version 13.0 to produce the KMO and Bartlett's test of sphericity (Table 1), eigenvalues, contribution rates of principal components (Table 2), and principal component loading matrices (Table 3). Each variable was standardized before performing the principal component analysis.

Table 1. Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity.

		ξ1	ξ2	ξ3
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.84	0.76	0.84
Bartlett's Test of Sphericity	Approximate Chi-Square	470.48	467.21	469.06
	Degree of Freedom	45	45	45
	Significance Level	0	0	0

Note: ξ1 refers to the Baota District, ξ2 to Yan'an, and ξ3 to the northern Shaanxi region.

Table 2. Eigenvalues and contribution rates of the principal components.

	Eigenvalues			Contribution rates (%)			Cumulative contribution rates (%)		
	ξ1	ξ2	ξ3	ξ1	ξ2	ξ3	ξ1	ξ2	ξ3
1	7.26	7.62	5.91	72.61	76.21	59.12	72.61	76.21	59.12
2	1.21	1.12	2.38	12.13	11.17	23.81	84.75	87.38	82.93
3	0.72	0.71	0.57	7.20	7.12	5.68	91.95	94.50	88.61
4	0.44	0.28	0.5	4.38	2.77	5.01	96.33	97.27	93.62
5	0.16	0.17	0.35	1.57	1.71	3.51	97.89	98.99	97.13
6	0.10	0.05	0.17	0.97	0.52	1.68	98.86	99.51	98.81
7	0.07	0.03	0.08	0.75	0.32	0.81	99.61	99.83	99.62
8	0.02	0.01	0.03	0.18	0.12	0.28	99.79	99.96	99.90
9	0.01	0.00	0.01	0.13	0.04	0.10	99.92	99.99	99.99
10	0.01	0.00	0.00	0.08	0.01	0.00	100	100	100

Note: Eigenvalues were extracted through principal component analysis. ξ1 refers to the Baota District, ξ2 to Yan'an, and ξ3 to the northern Shaanxi region.

Table 3. Loading matrix of the principal components.

	Principal component 1			**Principal component 2**		
	ξ1	**ξ2**	**ξ3**	**ξ1**	**ξ2**	**ξ3**
X_1	0.86	0.83	0.61	0.46	0.46	−0.15
X_2	0.86	0.82	−0.01	−0.04	0.03	−0.77
X_3	0.81	0.95	0.25	0.52	0.20	0.55
X_4	0.90	0.97	0.91	0.20	0.04	0.20
X_5	0.92	0.96	0.94	0.10	0.16	0.18
X_6	0.95	0.97	0.94	0.28	0.17	0.18
X_7	0.58	0.98	0.97	0.81	0.13	0.04
X_8	0.60	0.80	0.97	0.70	0.50	−0.07
X_9	0.53	0.62	0.54	0.68	0.56	−0.40
X_{10}	0.09	0.03	−0.10	−0.80	−0.89	0.44

Note: ξ1 refers to the Baota District, ξ2 to Yan'an, and ξ3 to the northern Shaanxi region.

The Kaiser-Meyer-Olkin (KMO) and Bartlett tests were performed at three scales before the principal component analysis (Table 1). The values of the KMO tests for the Baota District, Yan'an City and the northern Shaanxi region are all greater than 0.7, and the spherical Bartlett tests were significant, which indicated that the variables could provide a reasonable basis for principle component analysis. As shown in Table 2, the cumulative contribution rates of the first and second principal components were 84.75%, 87.38%, and 82.93% for the Baota District, Yan'an City and the northern Shaanxi region, respectively, which fully met the requirements for the analyses. Based on the analysis of the loading matrices of the principal components, the first principal component of the Baota District showed greater absolute load values for population change, urbanization, and socio-economic development, whereas the second principal component showed greater absolute load values for agricultural modernization and environmental factors. Among the important driving factors for Yan'an, population increase, urbanization, socio-economic development, and agricultural modernization exhibited a greater factor load value for the first principal component, whereas the environmental factors exhibited greater absolute load values for the second principal component. For the northern Shaanxi region, socio-economic development and agricultural modernization exhibited greater load values for the first principal component, whereas the agricultural population exhibited the greatest load value for the second principal component (Table 3).

3.2.2. Analysis of the Correlation between Changes in Arable Land Area and the Major Driving Factors

Canonical correlation analyses were performed upon the dependent variables, year-end actual arable land area (Y_1), crop yield per unit area (Y_2), and generated principal components. The p-values for the correlation coefficients were smaller than 0.05 and significant. The results of the canonical correlation analysis (Table 4) demonstrated that principal component 1 had a greater impact on the year-end actual arable land areas in Yan'an and the northern Shaanxi region, whereas principal component 2 exerted a greater impact on the Baota District. The crop yields per unit area in the Baota District, Yan'an City and the northern Shaanxi region exhibited larger correlation coefficients with principal component 1.

The results of the principal component analysis suggested that the modernization of agricultural technology had a large impact on the year-end actual arable land area in the Northern Shaanxi region at multiple scales, whereas the environmental factors exerted greater impacts on the changes in the year-end actual arable land area at the smaller scales. The impact of socio-economic development became the predominant factor affecting the changes in the year-end arable land area for the city and region scale. The crop yield per unit area for the Baota District was a result of the combined impact of population, urbanization, and socio-economic development. In addition to the impact of population, urbanization, and socio-economic development, the modernization of agriculture technology also played an important role in impacting the crop yield per unit area for the Yan'an City. However, in the northern Shaanxi region, socio-economic development and the modernization of agricultural technology rather than population growth and urbanization were the critical factors affecting the changes in the crop yield per unit area at this largest scale. This observation is a reflection of the demographic changes, urbanization, and socio-economic development directly or indirectly affecting the changes in the crop yield per unit area at the smaller scales. The impact of socio-economic development and the modernization of agricultural technology were more predominant with increasing scale, and these were the primary factors affecting the change in the crop yield per unit area.

From the above analysis， we found that the modernization of agricultural technology had a large impact on the year-end actual arable land area in the northern Shaanxi region. This phenomenon may have some connection with the special environmental and geographical environment of the northern Shaanxi region in the Loess Plateau, which has abundant hilly and mountainous areas that make the landscape fragmented. Therefore, it would be difficult to reclaim land simply by relying on human labor. The agricultural modernization technology of the northern Shaanxi region was relatively primitive prior to 1980. The modernization of agricultural technology includes the total power of the agricultural machinery and agricultural consumption of chemical fertilizers in the research. The total power of the agricultural machinery played an important role in the reclamation of the arable land in the northern Shaanxi region with the technological progress of agricultural modernization.

Table 4. Correlation coefficients between the dependent variables and principal components.

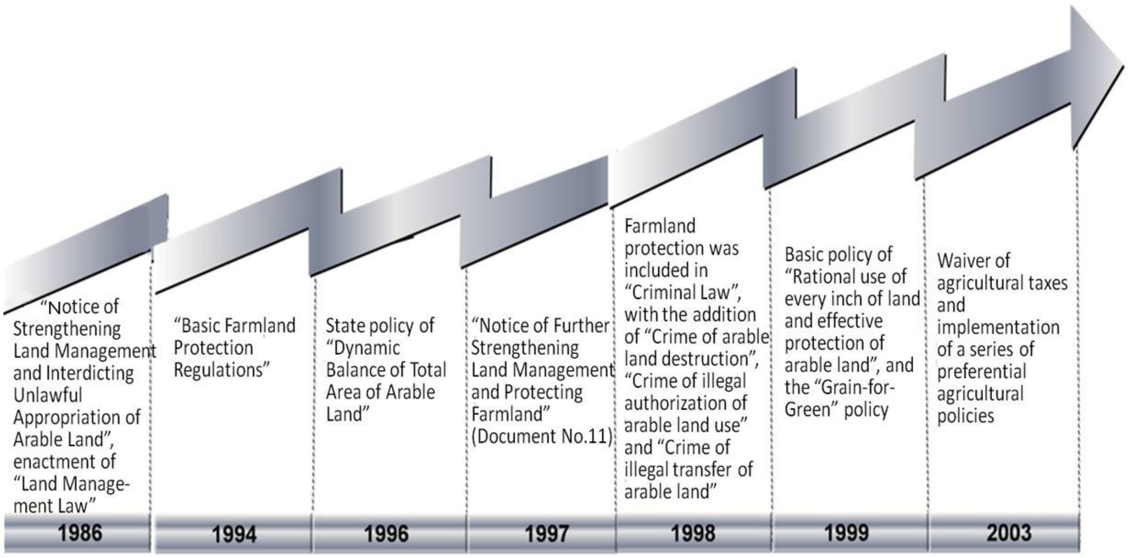
	Y_1			Y_2		
	ξ1	ξ2	ξ3	ξ1	ξ2	ξ3
Principal component 1	−0.34	−0.85	−0.81	0.52	0.88	0.40
Principal component 2	−0.52	−0.33	0.18	0.49	0.21	−0.19

Note: ξ1 refers to the Baota District, ξ2 refers to Yan'an, and ξ3 refers to northern Shaanxi region; Y_1 refers to year-end actual arable land area, and Y_2 refers to crop yield per unit area.

3.2.3. Analysis of the "Grain-for-Green" Policy Factors that Produce Changes in Arable Land

Land resource is very precious, and available land resources as well as arable land resources are lacking in China. So the Chinese government always attaches great importance to the protection of arable land [20]. National arable land protection policies are important factors that produce changes in arable land. And the government has developed a series of key guidelines and policies (Figure 5) that stress the need for strengthening land management to ensure the protection of arable land. The contributions of the policies of the national government to the arable land changes were qualitatively analyzed. During the period 1980–2010, the national arable land protection policies produced the changes in the arable land in the northern Shaanxi region to some extent. In particular, the "Grain-for-Green" policy, which was implemented with the goal of improving ecological security in 1999, involved the conversion of arable land to forests or grasslands [21]. After the implementation of the "Grain-for-Green" policy by the state in 1999, the change curves for the year-end arable land proportion of the total area at the three scales (the Baota District, Yan'an City, and northern Shaanxi region) were compared, and the data demonstrated that the Grain-for-Green policy was not an important factor affecting changes in the arable land in the Baota District. However, the policy had a significant impact on changes in the arable land in Yan'an City and the northern Shaanxi region where the arable land areas have decreased rapidly since the implementation of the Grain-for-Green policy in 1999. The average rates of the decline in arable land area in Yan'an City and the northern Shaanxi region were 4.2% and 4.5%, respectively, whereas the rates of decline in arable land area in the Baota District was smaller than 0.1% from 1999 to 2003, which suggested that the policy had a more significant impact on the changes to arable land at larger scales.

Figure 5. State policies related to arable land protection implemented between 1980 and 2010.



4. Conclusions

The crop yield per unit area and arable land area were used as indicators of the changes in arable land in the Loess Plateau of northern Shaanxi. Using a canonical correlation analysis, qualitative analysis and principal component analysis, significant scale effects were observed for the changes in the arable land area and corresponding driving forces in the three areas of increasing spatial scale (the Baota District, Yan'an City, and the northern Shaanxi region).

The area of arable land exhibited a gradual downward trend at the three spatial scales, and the year-end actual arable land proportion of the total area in the northern Shaanxi region and Yan'an City had similar trends, whereas the proportion in the Baota District had no obvious similarity with the northern Shaanxi region and Yan'an City. Over the years, the crop yield per unit area displayed a complicated upward trend within the same studied scales, although the yield showed significant changes at different scales. For each year from 1980 and 2001, crop yields per unit area were observed to be lowest at the highest spatial scale within the same year. From 2002 to 2010, the crop yield per unit area in Yan'an exceeded that of the Baota District, whereas the crop yield per unit area in the Baota District was still higher than in the northern Shaanxi region.

Significant differences were observed among the factors driving the changes in arable land at the different scales. Modernized agricultural technology had the greatest impact on the change in the year-end actual arable land area of the Baota District, Yan'an City, and the northern Shaanxi region. Environmental factors had a greater impact on the change in the year-end actual arable land area at the smaller scales. The impact of socio-economic development became the predominant factor affecting the change in the year-end arable land area for the city and regional scales. At the smaller scales, population change, urbanization and socio-economic development affected the crop yield per unit area either directly or indirectly. The effects of socio-economic development and modernized agricultural technology became predominant with increasing spatial scales and were the major factors affecting the crop yield per unit area.

In addition, government policies had a more significant effect on the changes in arable land at larger scales. In Yan'an City and the northern Shaanxi region, the area of arable land exhibited a rapid decline since the implementation of the Grain-for-Green policy in 1999, and the average rate of arable land decline exceeded 4% from 1999 to 2003 for both areas. In contrast, government policies did not have an apparent effect on the arable land in the Baota District. A number of local water and soil conservation policies also influenced the changes to the arable land in the studied areas.

This study analyzed the changes in the arable land area and the associated driving forces for three areas representing increasing the spatial scales. The changes in the arable land area and the associated driving forces exhibited significant scale effects for the three areas representing the increasing spatial scales. Current research on changes in arable land and its driving forces are mostly concentrated in one single scale, and the studies of its scale effects are relatively rare. Studies have shown that the main driving factors of the changes in arable land in Shaanxi Province were socio-economic development and the Grain-for-Green policy; main driving factor contributing to the changes of arable land in Yan'an City was socio-economic development; main driving factor contributing to the changes of arable land in Ansai County, Yan'an City were the environmental and socio-economic development [22,23]. Summarizing these studies, we can concluded that environmental factors had larger impact on the changes in arable land at smaller scales, whereas the Grain-for-Green policy was a major driving factor for changes in the arable land at larger scales and socio-economic development played an important role in the changes in the arable land at multi-scales. This conclusion was similar to our results, but they were not entirely consistent. The primary reasons for these differences may be as follows: differences in regions, differences in the index factors and analytical methods, and differences in data sources. Further studies on these differences and their driving forces are required, and in-depth research on the quantitative analysis of policy factors is also required.

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Author Contributions

Lina Zhong made substantial contributions to the acquisition of data, analysis and interpretation of the data and drafting and revising the article; Wenwu Zhao made substantial contributions to the concept and design of the article, helped to revise the manuscript, and produced the final approval of the version; Zhengfeng Zhang provided good advices throughout the paper, and contributed to the manuscript revisions; and Xuening Fang helped to revise the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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