Assessment of ecological security based on soil and water conservation: a case study from Gansu Province, China

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Abstract. In this study, the analytic hierarchy process (ahp), ecological security index (S) and PSR model were used to evaluate Gansu’s ecological security based on the large number of survey data. The results indicated that Gansu's ecological security index increased from 0.31 in 1986 to 0.66 in 2013, which reflected ecological security was in sensitive state (0.7 > S ≥ 0.5). The main reason was that national policy on protecting the ecological environment has played a crucial role, especially the national project of returning farmland to forest and grass carried out in recent years. Moreover, the environmental issues such as the higher PM2.5, sand storms and climate extremes, had significantly improved people's environmental awareness in the study area. The regional difference of ecological security index was significant in Gansu Provinces, and the part of Yangtze river basin was higher than the part of Yellow River basin, whiles the in-land river basin was the lowest value. In a world, Gansu's ecological security had improved in recent years, but there was strong need for paying more attention to policy for ecological environment protection and increasing the propaganda to ensure the Gansu's ecological security in the future. This study will provide a scientific basis for the sustainable development of regional social economy and ecological environment.

1. Introduction
In 1989, the concept of "ecological security" and the global ecological security status monitoring were firstly put forward by the international institute for applied systems analysis (IIASA) [1-6]. National security strategy report of the United States also proposed the ecological environment security will bring into the category of national security in 1991[7-9]. The concept of ecological security has caught extensive debate from the international society and since then the world has begun to study ecological security [10-13]. Ecological security is not only confined to the ecosystem security, but the national security constituted by political security, military security and economic security [14-15]. However, political security, military security as well as economic security are the important guarantee for
ecological security [16-18]. Worldwide ecological environment situation is not optimistic and many countries and regions have seen the deterioration of the environment [4]. And this eventually led to the destruction of the normal order of production and life and caused the serious economic losses. Thus to ensure the ecological security has become a pressing social needs, and the extensive study of ecological security has also become common in the world [19].

To some extent, the ecological safety is human survival safety. Jiang [20] et al (2011) thought that ecological safety was a state of healthy and sustainable development for human survival environment, whiles Yao [21] believed that the ecological security was a stable and sustainable ecosystem system, but which played a supporting role in human society and economy system. Excessive interference or disaster will damage the structure and function of ecosystem, so the ecological security situation will be threatened. Norton [22] founded that ecological security could maintain the survival and development of its normal state and it is the human survival environment. Considering from the perspective of national ecological safety, ecological security problem is a wider range of disorders in ecological structure, and it has affected the normal operation[23]. In addition, Rapport[24] argued ecological security and sustainable development of human society might have common sense, and the goal was to provide continuity and good ecological service function for sustainable development.

Gansu Province is located in northwestern China with complex terrain and climate, where located in loess plateau, mainly including the part of Yangzi river basin, Yellow river basin and Chinese in-land river basin. The loess geomorphy leads to cultivated soil resources become less and less. Finally, the problem of ecological security is becoming increasingly serious. However, the research on regional ecological security is rare. In recent decades, there has been many achievements about ecological security research at home and abroad focused on big cities of ecological security and ecosystem security, and the evaluation index system involves social, economic, natural, etc., and these researches have various forms and characteristics[25-29] . Selecting Gansu Province as the research area, this research employed soil and water conservation measures as index for evaluating the ecological security situation. This study firstly calculated the ecological security index in three sub-basins, respectively, and then analyzed the Gansu's ecological safety from the angle of time and space. Furthermore, the research put forwards the soil and water conservation measures in order to improve the regional ecological environment of Gansu Province. Finally, this research discussed the relationship between ecological safety and sustainable development, and argued that the sustainable development provides standardized guidelines for achieving human security. The quantitative evaluation for Gansu's ecological security will provide the scientific evidence for improving ecological environment in the future. At the same time, the result can provide a direction for government and lay a solid foundation for further research of ecological security.

2. Study area
Gansu Province(92°-108°E, 32°-42°N) located in the northwestern China, which lied in the interaction belt among loess plateau, the Mongolia plateau and the Tibet Plateau. Stretching 1,665 km from west to east and extending 530 km from south to north, with an area of 454,400km², the territory has high terrain and topography is complex. Mountain, plateau, valley, desert and Gobi desert staggered, hilly and mountains area accounts for more than two-thirds of the total area. Altitude ranges from 1,000 m to 5000 m. Terrain is tilt from the northwest to southeast, and the natural landscape exhibited an
obviously vertical change with the significantly horizontal zonally. The regional differences of climate is significant characterized by the arid climate, little rain and abundant sunshine. The variational rate of precipitation and temperature is very large. The multiyear average temperature of the whole Province ranges from 0 to 14 °C, whiles annual precipitation is 280.6 mm. Vegetation from south to north showed the obviously latitude zonal distribution influenced by natural factors such as latitude, climate and landform. Area of forest vegetation is narrow and mainly distributed in certain high level for the Qilian mountains, Longnan mountains and Gannan grassland, whiles it is grassland and desert steppe below the forest belt and is alpine meadow and sub ice sparse vegetation and alpine snow belt above the forest belt. The study region can be divided into the parts of Yellow river basin, the Yangtze River basin, and in-land river basin. The area of Yellow river basin part is 145,523 km$^2$, and water erosion area is 112,534 km$^2$. The area for Yangtze River basin is 38,364 km$^2$, and water erosion area is 23,278 km$^2$. The in-land river basin area is 269,807 km$^2$, and the water erosion area is 35,986 km$^2$ and the wind erosion area is 223,642 km$^2$. Soil and water loss has seriously affected and restricted the regionally economic and social sustainable development and the smooth realization of the comprehensive construction well-off society goal.

Gansu is the most serious soil and water loss in China, soil erosion, wide area, multi type, heavy damage and hard treatment. Over the years, Gansu has organized a small watershed comprehensive management and Terrace construction engineering based on the situation in the Province. It has played a positive role in prevention and control of soil and water loss, improving the ecological environment, natural disaster reduction, and improving the land bearing capacity. But soil erosion governance progress slowly, without restraint use has not been completely reversed, redevelopment, light protection, heavy eyes, light long-term traditional concept still exists. The fundamental reasons lie in the lack of management system, lower cost of resource usage as well as breaking the law. ambiguous property rights of the soil and water maintain facilities and uncertainty soil and water conservation ecological function region division. The system of paid use of land and water resources has not yet been established, soil and water conservation ecological compensation mechanism has not been formed. On the basis of analyzing the concept innovation, mechanism innovation and measure innovation of ecological civilization construction, the concrete measures to strengthen soil and water conservation and promote ecological civilization are put forward.

![Figure 1](image-url)
3. Materials and methods

3.1 Data Collection

Soil and water conservation data came from the database “National water resources census and National soil erosion remote sensing investigation” and “Bulletin of Soil and Water Conservation data in Gansu Province in China”. Other data were from “Statistical Yearbook of Gansu” and “Rural Economy Yearbook of China” (Table 1). All the index values were calculated based on the data collected from these databases.

Table 1. The data sources of this study.

| Index layer                                      | Data source                              | Time          |
|-------------------------------------------------|------------------------------------------|---------------|
| The area of cultivated land per capita(hm$^2$) P1 | Statistical Yearbook of Gansu and Rural Economy | 1987-2014     |
|                                                 | Yearbook of Gansu                        |               |
| The amount of fertilizer per area (kg/hm$^2$) P2 | Statistical Yearbook of Gansu and Rural Economy | 1987-2014     |
|                                                 | Yearbook of Gansu                        |               |
| The amount of pesticide per area(kg/hm$^2$) P3  | Statistical Yearbook of Gansu and Rural Economy | 1987-2014     |
|                                                 | Yearbook of Gansu                        |               |
| The ratio of natural disasters inundated area P4 | Statistical Yearbook of Gansu and Rural Economy | 1987-2014     |
|                                                 | Yearbook of Gansu                        |               |
| The control area ratio of water loss and soil erosion P5 | Statistical Yearbook of Gansu and Rural Economy | 1987-2014     |
|                                                 | Yearbook of Gansu                        |               |
| The forest area of soil and water conservation(hm$^2$) P6 | Bulletin of Soil and Water Conservation Data in Gansu | 1987-2014     |
| The area of artificial grass (hm$^2$) P7        | Bulletin of Soil and Water Conservation Data in Gansu | 1987-2014     |
|                                                 |                                          |               |
3.2 Construct evaluation index system

Based on the data of soil and water conservation in Gansu Province, the choice of ecological security evaluation index should not only consider the environment condition of agricultural ecosystem, but also reflect the potential impact on the important factors of soil and water conservation, and what’s more, it must reflect the characteristic of regional agriculture ecological security evaluation [30]. Therefore, establishing the ecological security evaluation index system must follow the principle of scientific, objective, comprehensive system, relative independence, pertinence, operability and comparability [31].

Thus, this paper consulted the relevant literature about ecosystem safety evaluation, and combined with implementation status of soil and water conservation from 1986 to 2013 in Gansu Province, the present agriculture resources situation and the trend of rural economy development. Through the analysis of the main factors affecting agriculture and agricultural development, this research selected 12 indexes to build ecological security index system based on soil and water conservation of Gansu Province (Table 2).

3.3 Data analysis

| Index layer | Data source | Time          |
|-------------|-------------|---------------|
| The area of closing hillsides to facilitate afforestation (hm²) | Bulletin of Soil and Water | 1987-2014 |
| The area of closing hillsides to facilitate grass(hm²) | Bulletin of Soil and Water | 1987-2014 |
| The investment amount of soil and water conservation (million) | Statistical Yearbook of Gansu and Rural Economy | 1987-2014 |
| The grain output per capita(t) | Statistical Yearbook of Gansu and Rural Economy | 1987-2014 |
| The agricultural output value per unit area (million/km²) | Statistical Yearbook of Gansu and Rural Economy | 1987-2014 |

| Index layer | Data source | Time          |
|-------------|-------------|---------------|
| Time        |             |               |
| 1987-2014   |             |               |

5
3.3.1 Index standardization. For the original data in this study, it showed some different dimensions, and the order of magnitude also had the obvious difference. Therefore it is necessary to standardize the original data before analysis. At first, original data was calculated by extreme value method, and then confirmed each index between 0 and 1[32-33]. Considering the influence about each index to the system existed differences, the index value, the better development degree is. For others, the smaller the value is, the better is. The former is positive index, and the latter is negative one. So different evaluation index had different quality and its dimension was also different. In order to eliminate the hard evaluation from different dimensions, original data was adopted to improve the standardization using the normalization method before calculation[15].

For the positive effect index, which means this kind of index has much less risk to ecological security. The standardization values can be calculated by:

\[
P_{ij} = \frac{x_{ij} - x_{ij}^{\max}}{x_{ij}^{\max} - x_{ij}^{\min}}
\]  

(1)

For the negative effect index, which means this kind of index has much more risk to ecological security. The standardization values can be calculated by:

\[
P_{ij} = \frac{x_{ij} - x_{ij}^{\min}}{x_{ij}^{\max} - x_{ij}^{\min}}
\]  

(2)

Where, \(P_{ij}\) is normalized value; \(x_{ij}\) as the actual value; \(x_{ij}^{\max}\) is biggest value of this index, and \(x_{ij}^{\min}\) is the minimum value of this index.

3.3.2 Weight determination. As a kind of objective value assignment method, the method of mean square error has been adopted to evaluate objectively Gansu's ecological security. Its weight is formed by actual data from unit of each index in the evaluation [34-35], whereas it does not depend on man's subjective judgment, and it is strong objectivity. The formula is as following:

\[
E(A_i) = \frac{\sum_{j=1}^{28} P_{ij}}{28}
\]  

(3)

\[
V(A_i) = \sqrt{\frac{\sum_{j=1}^{28} (P_{ij} - E(A_i))^2}{27}}
\]  

(4)

\[
\xi = \frac{V(A_i)}{P}
\]  

(5)

\[
W_i = \frac{\xi}{\sum_{i=1}^{12} \xi}
\]  

(6)
\[
S = \sum_{i=1}^{12} Wi \times P_{ij}
\]

(7)

Where \( S \) is the value of ecological safety degree, the \( \{A_i \ (i = 1, 2, 3, \ldots, 12) \} \) is index series, \( \{G_j \ (j = 1, 2, 3, \ldots, 28)\} \) is solution series from 1986 to 2013, respectively, \( P_{ij} \) is the attribute values for solution series to index series. Firstly, \( P_{ij} \) by equation (1), (2) was calculated and then the average value for the standardized \( A_i (P) \) and its variable coefficient (\( \xi \)), and the mean square error for \( G_j (V(A_i)) \) were calculated; Secondly was to confirm the weight of each index (\( W_i \)) using equation (3), (4), (5), and (6); Finally the ecological safety degree was calculated by the equation (7).

**Table 2. Weight of ecological security evaluation index system for soil and water conservation of Gansu Province.**

| Target layer | Rule layer | Index layer | Index weight |
|--------------|------------|-------------|--------------|
| The pressure indicators of ecological environment \((G1)\) | The area of cultivated land per capita \((hm^2)\) \( P_1 \) | 0.0792 |
| The amount of fertilizer per area \((kg/hm^2)\) \( P_2 \) | 0.0866 |
| The amount of pesticide per area \((kg/hm^2)\) \( P_3 \) | 0.0976 |
| The ratio of natural disasters inundated area \( P_4 \) | 0.0577 |
| The control area ratio of water loss and soil erosion \( P_5 \) | 0.0807 |
| The forest area of soil and water conservation \((hm^2)\) \( P_6 \) | 0.0883 |
| The area of artificial grass \((hm^2)\) \( P_7 \) | 0.0771 |
| The area of closing hillsides to facilitate afforestation \((hm^2)\) \( P_8 \) | 0.0883 |
| The area of closing hillsides to facilitate grass \((hm^2)\) \( P_9 \) | 0.0914 |
| The investment amount of soil and water conservation \((million)\) \( P_{10} \) | 0.0915 |
| The grain output per capita \((t)\) \( P_{11} \) | 0.0707 |
| The agricultural output value per unit area \((million/km^2)\) \( P_{12} \) | 0.0874 |

### 3.4 Grading standard of ecological security

It has been reported that it is very hard to directly judge the ecological security situation through calculating the ecological security degree [36]. Therefore, this study divided the ecological security degree \((0 \text{ to } 1)\) into five ranks, on one hand, this research is based on the existing research results \([14,25,36]\) and consulting experts. On the other hand, this study divided the ecological security degree \((0 \text{ to } 1)\) into five ranks according to the relative index method referenced to other classification proofs, and in viewing of the present situation of soil and water conservation and ecological environment of the study area. The details for the ecological security ranks were showed in Table 3.
| Rank | Safe state | Ecological security degree(S) | Characteristics |
|------|------------|-------------------------------|-----------------|
| I    | Safe state | S ≥ 0.8                       | The function of land ecosystem service is perfect, the agriculture ecosystem environmental without interference, system structure and complete function is strong, the land is fertile, vegetation coverage rate is high, and there is no significant ecological problems |
| II   | Safer state| 0.8 > S ≥ 0.7                 | The function of land ecosystem service is relatively perfect, less the damage to agricultural ecological environment, system structure and complete function is less, the fertility of soil is stronger, the vegetation coverage rate is higher, the value agricultural output is high, the use degree of land is high, and ecological problems does not significant |
| III  | Sensitive state | 0.7 > S ≥ 0.5 | The function of land ecosystem service begin to degradation, agricultural ecological environment is interference, system structure has been deteriorating, but still can maintain the basic functions, the soil fertility is decrease, vegetation coverage is reduced, ecological disasters have occurred |
| IV   | Risk state | 0.5 > S ≥ 0.3                 | The function of land ecosystem service and agricultural ecological environment have been destroyed. The damage of system structure is bigger, and difficult to recover the interference. The soil fertility is lower, governance difficulties and ecological disasters become more and more significant |
| V    | Deteriorating state | S < 0.3              | The function of land ecosystem service and agriculture ecological environment are destroyed completely, the ecological environment system structure is incomplete and function is loss, ecological restoration and reconstruction is very difficult, the ecological environment problem is very big and ecological disasters often happened |

4. Results

4.1 Spatial variation of the ecological security degree
Through the systematic analysis on the three river basins and Gansu Province, the ecological security in most of the area had reached to the safety state in 2011. Figure 2 showed the spatial distribution of
the ecological security degree of Gansu Province in 1991, 2001 and 2011, respectively. The degree of ecological security increased from 0.31 in 1986 to 0.66 in 2013 based on the analysis of three major river basins. Ecological safety had improved with the ecological very difficult security job, whiles the average of ecological security changed from 0.36 to 0.59 in 14 cities (state) of Gansu Province. The rank of ecological safety was in the III, IV grade in study basin, which means the degree of ecological security increased, but land ecosystem service function degraded. The system structure had deteriorated after the disturbance for agricultural ecological environment, but can still maintain the basic function with the decreased soil fertility and vegetation coverage. The ecological problems and ecological disasters occurred occasionally. As Figure 2 showing, the Baiyin city, Gannan city and Jiayu-guan city were deteriorating state in 1991, whereas some cities were at risk state, such as Qingyang city, Pingliang city, Dingxi city, Lanzhou city, LinXia city and Jiuquan city, but it showed the sensitive state for Jinchang city, Tianshui city, Longnan city, Wuwei city, Zhangye city. In 2001, Baiyin city, Gannan city and Jiayu-guan city were deterioration, whiles risk cities were Qingyang city, Lanzhou city, LinXia city and Jiuquan city, and the sensitive cities was Dingxi city, Jinchang city, Pingliang, Zhangye and Wuwei, but Tianshui and Longnan were safer. In 2011, Baiyin, Gannan, Jiuquan city and Jiayu-guan city were in risk, whereas it displayed the sensitive state for Qingyang city, Dingxi city, Lanzhou city, LinXia city, Longnan city, Jinchang city and Wuwei city, and it was safety for Tianshui city, Pingliang city and Zhangye city.

![Figure 2](image_url). Spatial pattern of ecological security degree in 1991, 1986 and 2011.
4.2 Gansu’s Ecological security evaluation

Ecological safety in the whole Province had improved significantly from 1986 to 2013, and there wasn’t a city in risk state until 2013. This situation suggested that the ecological deterioration was significantly lower. Ecological security level was better mainly due to the increase of vegetation coverage in Gansu Province and the population control, and it also because of the local intensive production mode. The fluctuation of different level may be related to the importance of ecological environment protection and the way of the regional ecological environment protection. Qingyang city's ecological security increased year by year, changed from the deterioration state in 1991 to the sensitive state in 2011. This conclusion is similar to previous research [37]. Consistent with the study by Yang and Liu [38], Jinchang city’s ecological security improved gradually, from the sensitive to the safer state, and this result mainly due to the development of soil and water conservation and the protection of the east river water source conservation forests. Owing to Jiayu-guan city’s natural conditions of being limited and located in Gobi desert, its ecological deficit was larger. Therefore the ecological security state had been at risk state, but there was no denying that the ecological environment had changed. From deterioration state in 1991 to risk state in 2013, this was similar to the research by Zhang [39]. In addition, Tianshui city' ecological security was maintained in safer state from 1986 to 2013, its ecological safety was the most stable, and the main reason was that the destruction of the vegetation was less. Vegetation coverage was higher with the well-developing local’s soil and water conservation, and its benefit was also remarkable. Longnan city’s ecological security reduced from safety in 2001 to sensitive state in 2011, and its degree has declined. Zhangye city and Pingliang city have improved in 2011 and were in safety state. This may mainly due to the differences from each local government policy because it must revise the related policy immediately and ensured ecological security with good sustainable development.

5. Discussions

5.1 Ecological security zone differences in Gansu Province

5.1.1 Yellow River basin. Ecological security degree, pressure index, status index and response index from 1986 to 2013 in Yellow River basin were presented in Figure 3. The ecological security status for Yellow River basin can be concluded as following: it was in the risk state from 1986 to 2003, whiles it was in sensitive state during from 2004 to 2010, and it was much better than the former years and stayed in safety state until 2011 to 2013. The overall state was in risk state with the average of index value of 0.48 during the past 28 years.

It exhibited the lowest values (0.31) for ecological security degree in 1990, and the other three index values were kept comparatively low. The main reasons were the rapid growth of population in China leaded to the nervous land at that time. More people wanted to acquire more land, and Gansu Province located in Loess Plateau with the complex and varied topography, and the plains was preciously few. So people transfer their target to the mountains land and begin deforest and reclamation, and a large number of grassland and forest had been destroyed in the study area and caused the serious soil erosion. Until 1999, the destroying forest had obviously protect when the government put forward the policy of returning farmland to forest and grass, and it effectively...
maintain the water and soil through large-scale project of returning farmland to forest. And the ecological security degree was 0.47 in 1999, lower than in 2000 (0.38) because it was the first year for returning farmland to forest, and the project could result in serious destroy of the surface soil. The situation was gradually improving from 2000 to 2013 for the trend of soil and water conservation and ecological security in the whole basin. As the research by Li [1], Huining County, located in Gansu Province, where the remarkable achievements of returning farmland to forest, and the vegetation coverage has increased significantly under the implement of returning farmland to forest project, whiles the NDVI index increased area of vegetation is 4404.75 km² in 2011 comparing with 2000, accounting for 77.74% of the total area of Huining County.

As showing in Fig.3, pressure index showed the decreasing trend year by year, whiles state index and response index showed increasing trend. This is mainly due to the adjustment of national policy. People have become deeply awareness of the importance of protecting ecological environment, and it also closely related to the current control of population. This demonstrated the land ecosystem service function is relatively successful, and the damage to agricultural ecological environment has become less, whiles system structure is complete and the function is stronger with the stronger soil fertilizer, the higher vegetation coverage rate, the high agricultural output value and the high land use degree, but the significant ecological problems had not happened.

![Figure 3. Variation of ecological security degree for Yellow River basin from 1986 to 2013.](image)

5.1.2 Yangtze River basin. It had the lowest value (0.33) in 1986 for ecological security degree in Yangtze River basin, and status index and response index were also kept lowest, but pressure index was the highest (Figure 4). From 1986 to 1992, it was in risk state, while it was in sensitive state during from 1993 to 2010. However, it was much better than the former years and stayed in safer state until 2011 to 2013. For the past 28 years, the overall state was in sensitive state with the average value of 0.57. Ecological security had changed obviously in the Yangtze River basin from 1986 to 2013, and ecological security basically showed an increasing trend over the past 28 years (Figure 4).
Ecological security changed from risk state to safer state in 28 years, and ecological security degree increased by 127.27%, from 0.33 in 1986 to 0.75 in 2013. Land ecosystem service function was relatively perfect with less damage to agricultural ecological environment, and the soil fertility was stronger. It was high for the vegetation coverage rate and the agricultural output value with the high land use degree, and the ecological disasters decreased and agricultural output value increased year by year. And in August 2010, Zhouqu county catastrophic landslides occurred in the Southern Gansu where ecological security was at risk. This result was similar to the former view [40] because the region was in overload condition. Of course, the occurrence of debris flow was not an accident. Main reason was the geographic and geomorphic conditions, but human activity had also increased the likelihood of occurrence. Especially, the forest had been over-exploitation for the development of mineral resources, whereas the original vegetation was being destroyed. As figure.4 showing, pressure index showed the decreasing trend year by year, whereas state index and response index showed the increasing trend. The trend of the Yangtze River basin was consistent with Yellow River basin; the main reasons were people deeply awarded the importance of protecting ecological environment also closely related to the current control of population.

Figure 4. Variation of ecological security degree for Yangtze River basin from 1986 to 2013.

5.1.3 In-land River basin. For in-land river basin, ecological security degree presented a tendency of continuous improvement. And the degree increased by 37.50% from 0.40 in 1986 to 0.55 in 2013 (Figure 5). In generally, ecological security was from the risk stage to the sensitive stage. To some extent, this reflected the retention rate of the soil and water conservation measures was high with remarkable efficiency in in-land river basin. The bearing capacity of the ecological economic system was growing. However, three indexes presented obvious difference: pressure index showed a trend of decline dropped from 0.31 in 1986 to 0.15 in 2013. It showed the reduced trend for the pressure index contribution rate year by year. The main reason was that the regional population growth has caused water and soil resources pressure. Farmland area of per person is 0.43 hm² in 1986 but reduced to 0.21
hm2 in 2013 and it had dropped 51.16%. Status indicators also was risen generally with an increase from 0.05 in 1988 to 0.21 in 2013. This is mainly contributed by the result for the project of returning farmland to forest implements and the comprehensive treatment of soil erosion since 2000. Response index showed an increasing trend, from 0.03 (1986) to 0.19 (2013). The investment of soil and water conservation has increased from 21.13 Yuan per hm$^2$ in 1986 to 60.6 Yuan per hm$^2$ in 2013. The reverse trend for response index caused by two facts: on the one hand, it was due to the increased government investment for soil and water conservation year by year, on the other hand, owing to the output of grain per capita and agricultural output value per unit area caused by agricultural technology progress.

In in-land river basin, ecological security can be concluded as following: it was in risk state from 1986 to 1998, while it was in sensitive state from 1999 to 2013. For the purpose of measuring state during the past 28 years, the average value was 0.47, which means it was in risk state. So ecological security of in-land river basin still had a long way to reach the safety state, and it needs to do a lot of management work in the future.

Figure 5. Variation of ecological security degree for In-land river basin from 1986 to 2013.

5.2.1 Controlling the population growth and relieving the population pressure. In recent years, the Gansu provincial government had seriously implemented the national population control policy, and it has exhibited a preliminary results. However, there was a big gap to the international standards of ecological safety, so the government of Gansu Province should continue to strengthen the work of population control, strengthen population policy advocacy and guidance, especially for the cities with the great population pressure, such as Linxia, Tianshui, and Lanzhou city. And what’s more, the government should attach great importance to population issues, which combined with regional characteristics and land carrying capacity requirements to develop a reasonable population development planning and control population growth. For example, Linxia Prefecture as a Hui Autonomous Prefecture, population fertility concept is relatively outdated with a large number of
ethnic minorities, so the important significance of the people to focus on the promotion of fertility policy. For the capital city of Lanzhou, it is to carry out effective guidance with a large population base and a certain population agglomeration effects, which can ease population pressure by controlling the foreign population and other policies.

5.2.2 *Pay attention to agricultural technology innovation.* At present, the process of agricultural production in Gansu Province is more traditional because agricultural technology is not enough. There are many problems, such as the low production efficiency and the excessive use of chemical fertilizer. These problems not only damage the ecological environment, but also do not adapt to the requirements of modern society for agricultural products. Therefore, it is necessary to introduce new agricultural technology, cultivate agricultural production talents, promote green agriculture, and to reduce the amount of pesticide and chemical fertilizer. It is to arrange for the agricultural production from the region in different climate region in order to give full play to regional natural and resource advantages, such as in Jiuquan city and Gannan city. Owing to strong desertification land and the loess plateau in Gansu Province, soil is relatively poor, less rainfall, drought and water shortage but has plenty of light, heat and wind energy resources advantage. so it can take advantage of abundant energy to develop the plastic greenhouse and drip irrigation technology in the development of regional agriculture, with reasonable for the choose of crop species and planting measures, agriculture introduced the latest research results, in order to improve the plant the fixed conversion efficiency of solar energy.

5.2.3 *Increase capital investment, strict supervision mechanism.* In recent years, Gansu Province was mainly focused on economic development, which has caused many environmental problems in the process of industrial production with more waste water, waste gas, waste emissions, but with the lower governance rate and comprehensive utilization rate. It showed a continuous growth for GDP in Gansu Province during recent years, but it was in the lack of investment in environmental management. Some companies were focused on economic efficiency, but it ignored the long-term interests with excessive sewage phenomenon. And what’s more, environmental governance was not enough to catch up with the speed of pollution, whiles land pollution was becoming increasingly serious. It must reduce the industrial pollution in order to improve the utilization rate and treatment rate of industrial waste recycling.

Government departments should attach great importance to increased capital investment in environmental governance. The financial subsidies should support the enterprises to implement cleaner production engineering and development of raw materials and products. At the same time, government implement emissions of pollutants and sewage permit system for industrial pollution enterprises. It is combining with the characteristics of industrial enterprises, such as Qingyang city and Pingliang city with the coal enterprises, Yumen city with oil production enterprises, Jinchang city with copper and nickel ore enterprises, which are the serious pollution of heavy industry. Government must carry out strict control and supervision. The strict law must be enforced when found illegal polluters with the increasing punishment, investigating the corporate responsibility and raising the cost of corporate wrongdoing. These varieties of measures and methods have been executed to prevent and control environmental pollution and to improve "treatment after pollution" phenomenon under economic development.
6. Conclusions

Based on the observation data from 1986 to 2013, the results indicated that Gansu's ecological security degree increased from 0.31 in 1986 to 0.66 in 2013, and the ecological security was in the sensitive state (S<0.7). The main reason was that national policy on improving the ecological environment had played a decisive role in recent years, especially the project of returning farmland to forest and grass. These made people's environmental awareness has significantly improved in the study area. Ecological security also had the obvious regional differences. Yellow river's ecological security changed from risk state to safer state in 28 years, and ecological security degree increased from 0.36 in 1986 to 0.71 in 2013. Yangtze River's ecological security changed from risk state to safer state, and ecological security degree increased by 1.3 times. The ecological security degree for in-land river basin increased from 0.40 in 1986 to 0.55 in 2013 with an average value of 0.47. This may be largely due to the difference of geographical environment of the three major rivers of Gansu Provinces. In conclusion, although Gansu's ecological security had improved in recent years, the environment problem is still serious. There is a strong need for paying more attention to policy for ecological environment protection and increasing the propaganda in the future to ensure the Gansu's ecological security. The studies on ecological security are conductive to protect fragile ecological environment and local sustainable development. Ecological Security Assessment is a complex system engineering that involves many factors. The appraisal methods nowadays have their limits on selecting evaluating indicators, and the determination of the target weight may have some subjectivities. All the problems need to be further discussion and study, and the evaluation method is yet to be improved.

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