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Research on the Compensatory Effects of Fruit Tree Economic Forest on Soil and Water Conservation and Ecological Environment

Wang Fu, He Qian, Zhao Qiang, Sha Xiao Yan, Han Fen, Zhang He

Pingliang Institute of Soil and Water Conservation, Pingliang, China

Email address:

2640189616@qq.com (Wang Fu), 271685340@qq.com (He Qian), 365393688@qq.com (Zhao Qiang), 1039714213@qq.com (Sha Xiao Yan), 455573021@qq.com (Han Fen), 407645612@qq.com (Zhang He)

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Abstract: This paper closely follows the national strategic background of ecological protection and high-quality development in the Yellow River Basin, and focuses on the multiple realistic needs of soil and water conservation, water and sediment control, ecological protection, ecosystem restoration and ecological function improvement in the middle and upper reaches of the Yellow River Basin. With the multi-dimensional and multi-level compensatory effects of fruit tree economic forest on watershed scale soil and water conservation and ecological environment as the main research content and direction, in-depth research is conducted on the effects of watershed scale fruit tree economic forest coverage on reducing local soil and water loss, enhancing soil and water conservation ability, changing vegetation cover landscape pattern and the resulting ecological response in the loess hilly and gully region of Longzhong. This paper analyzes the compensatory effects of fruit tree economic forest on watershed scale soil and water conservation and ecological function increment change, and studies the scope, degree and magnitude of the impact, so as to provide theoretical basis and technical support for further coordinating the relationship between regional agriculture and forestry, economic development and ecological protection, and promoting the construction of a system management system of mountain, water, forest, farmland, lake and grassland in the loess hilly and gully region of Longzhong. At the same time, it provides reference for ecological protection and green high-quality development of the Loess Plateau in the middle reaches of the Yellow River of China.

Keywords: Fruit Economic Forest, Soil and Water Conservation, Ecological Environment, Compensatory Effects, The Hulu River Basin

1. Introduction

At present, the main viewpoints about the influence of artificial vegetation on regional soil and water conservation and ecological environment include:

(1) Most experimental and demonstration studies on ecological conservation and restoration mainly focus on small scale, local regional scope or a single community or vegetation type, and lack comprehensive studies and demonstrations at the regional scale from the whole watershed or system level, as well as optimization and regulation studies on the changes of existing models with the passage of time and the needs of economic development [1, 2].

(2) There are more studies on the ecological benefits and evaluation of artificial vegetation restoration, but there is a lack of comprehensive studies on the ecological function and structure of artificial forest ecological restoration. From the perspective of the technology and application research of ecological protection and vegetation restoration, the research on the optimal allocation and reconstruction of ecosystem structure and function and its regulation technology, as well as the restoration and maintenance technology of species and biodiversity have been successfully tested and studied. However, there is a lack of research on the

optimal allocation of ecological structure and function at basin scale and its regulation techniques, as well as the restoration and maintenance of species and biodiversity brought about by plantation construction at basin scale [3, 4].

(3) In the research on artificial vegetation promoting ecological restoration, the experimental demonstration of effective plant community models (without considering land use structure problems) has been obtained, and the study of plant diversity and microclimate change in the restoration process has been emphasized. However, there is a lack of research on the effects of plantation vegetation on plant diversity and microclimate change at catchment scale under the condition of cross-land use [5, 6].

(4) The most important is that the development process and demand change of catchment scale economy and the optimal allocation and regulation of catchment scale soil and water conservation and ecological structure and function are ignored [7, 8].

Although there are many researches on the engineering, technology and mechanism of ecological restoration in arid and semi-arid soil erosion areas at regional and watershed scales, and a large number of experimental observations have been produced, there has been no report on the impact of fruit tree economic forest as a homogeneous plantation vegetation patch embedded in the typical landform in the loess hilly and gully region on soil and water conservation at watershed scales. [9-11]

2. Research Content

On the basis of summarizing and analyzing the existing research results, main viewpoints and main arguments, this paper also refers to the theories, practices and methods of studying the effects of artificial vegetation on watershed scale soil and water conservation and ecology at home and abroad. As the main artificial vegetation cover in the Hulu River Basin in Pingliang City, the effects of integrated fruit tree economic forest on the optimization of vegetation landscape pattern at the catchment scale, the improvement of ecological functions in the basin and the multiple superimposed compensation effect of soil and water conservation have been mainly studied in the following aspects:

(1) Investigation, analysis and evaluation of the current situation of fruit economic forest in the Hulu River Basin.

(2) Research on soil and water conservation effects and ecological functions of fruit tree economic forests in the Hulu River Basin, including:

The influence of canopy interception and litter water retention on the reduction of surface runoff formation in fruit tree economic forest;

The influence of fruit tree economic forest on drainage and sediment reduction at watershed scale;

Influence of fruit tree economic forest on soil water cycle regulation at watershed scale;

Influence of fruit tree economic forest on watershed scale microclimate change.

(3) Research on ecological function service value and carbon sink of watershed scale fruit tree economic forest.

(4) Comparative analysis of ecological function service value and ecological function quantity between fruit tree economic forest and soil and water conservation forest.

3. Research Results

3.1. Realization of Research Goal

3.1.1. Coordinating of Agriculture and Forestry, Economic Development and Ecological Protection

Through the research on ecological function service value of fruit tree economic forest in the Hulu River basin and the comparison analysis with the annual output value of fruit tree economic forest in the same period, the results show that: The change range of eco-service economy ratio of fruit tree economic forest in Huluhe River Basin from 2005 to 2020 is 1.98 ~ 7.95, in which the eco-service economy ratio of fruit tree economic forest in 2020 is 2.12, that is, the total value of ecological services is 2.12 times of the annual fruit output value in the same period. It can be seen that fruit economic forest not only provides a large number of fresh fruit products, creating huge economic and social benefits for people, but also has huge ecological service value. The contribution of local GEP is greater than the contribution of GDP, and its potential ecosystem service value cannot be ignored.

Through the study of ecological service value and ecological function quantity of fruit tree economic forest and comparison analysis with soil and water conservation forest in the same period, the results showed that: Although fruit tree economic forest and soil and water conservation forest in loess hilly and gully region have great differences in forest type and use, there is no significant difference in water conservation, oxygen release, carbon sequestration, nutrient accumulation, soil conservation, fertility maintenance, species conservation, environment purification, negative ion provision and other ecological function service value. It can be seen that fruit tree economic forest not only creates economic value, but also provides ecological service value almost similar to that of soil and water conservation forest, which can not be replaced by other crops on agricultural land. Therefore, the cultivation and management of fruit tree economic forest in the Hulu River basin in Pingliang City should be paid enough attention. It can not only adjust the agricultural industry structure in the region, contribute a considerable amount of local GDP, but also maintain the regional ecological function and contribute enough GEP, with double value contribution. In terms of the output of main ecological functions, such as soil quantity and soil fertility, the fruit tree economic forest is larger than the soil and water

conservation forest. Therefore, fruit tree economic forest also has the ecological function of ecological public welfare forest, which is manifested as:

(1) To maintain the balance of regional hydrological cycle by retaining runoff and conserving water source through tree crown;
(2) Reduce soil and water loss, maintain soil and water resources, and reduce soil fertility loss through soil consolidation;
(3) Absorb CO_2 and release O_2 through photosynthesis to promote the accumulation of nutrients;
(4) By absorbing SO_2, nitrogen oxides, fluoride, dust fall, etc., reduce the content of particulate matter and toxic and harmful substances in the air, reduce the concentration of PM2.5, greatly improve the regional environmental quality, and effectively purify the environment by releasing a large number of negative oxygen ions, which is conducive to human health;
(5) In the loess hilly and gully region, a certain scale of fruit tree economic forest coverage has changed the spatial pattern of regional land use, greatly enhanced the continuity and ductility of the limited forest and grass vegetation, which is conducive to the conservation and reproduction of species in the region, maintained and enhanced the biodiversity of the region, and promoted the harmonious coexistence between man and nature.

Due to the extreme importance of fruit tree economic forest cover for ecological maintenance and soil erosion prevention in ecologically fragile areas of the Loess Plateau, the possible ecological public welfare loss caused by the adjustment of fruit tree economic forest must be considered first when adjusting the industrial structure.

The above research results are helpful to coordinate the relationship between agriculture and forestry, economic development and ecological protection in this region.

3.1.2. Construction of Governance System

Through the study on the soil and water conservation effect and ecological function of fruit tree economic forest in the Hulu River Basin, the results show that the coverage of fruit tree economic forest in the basin has a compensatory impact on improving the actual and effective vegetation coverage at the basin scale, retaining mud and reducing sediment, regulating the hydrological cycle of the basin, and improving the microclimate of the basin, which are as follows:

(1) The contribution rate of fruit tree economic forest to the vegetation coverage rate of forest and grass increased from 19.09% in 2012 to 29.23% in 2020, and the actual effective vegetation coverage rate of forest and grass in the basin increased from 32.96% in 2012 to 57.86% in 2020. The actual effective vegetation coverage rate is almost 59.14% in the eastern Jinghe River basin.
(2) Fruit tree economic forest litter has a huge water holding capacity, the maximum annual water holding capacity is 1285675.3t, the maximum effective storage total is 12444723.4 t;
(3) Pearson correlation analysis showed that the negative correlation between sediment transport modulus and fruit economic forest cover was $y=2680.258-2.506\times10^{-4}x$;
(4) The effects of fruit-tree economic forest on catchment scale hydrological cycle regulation are as follows: natural precipitation retention, canopy interception and litter water retention, canopy shade and water retention, soil infiltration and water storage.
(5) The coverage of fruit tree economic forest has the effects of cooling, temperature accumulation, humidification and moisture, and wind speed reduction on the underlying surface of the basin to a certain extent, which is conducive to improving the microclimate of small watershed, as follows: the average daily temperature in the forest decreases by 0.1 ~ 3.0°C compared with the average air temperature in the open land outside the forest, and the regulation effect of fruit tree economic forest is higher than that of water conservation forest; The cumulative temperature effect made the daily maximum temperature in the forest higher than that in the open area outside the forest by 0.4 ~ 1.1°C. The humidification and moisturizing effect makes the relative humidity of air in the forest increase by 3.2% ~ 11.1% compared with that outside the forest, and the average daily wind speed of air in the forest is 0.4m/s ~ 4.0m/s lower than that outside the forest.

The above provided theoretical basis and technical support for promoting the construction of the system governance system of mountains, rivers, forests, fields, lakes and grasslands in the loess hilly and gully region of Longzhong.

3.2. Breakthroughs in Key Technologies

3.2.1. Climatological and Ecological Significance of Fruit Tree Economic Forest Cover

Through the study of the actual effective vegetation cover of fruit tree economic forest at watershed scale, the results show that: The proportion of fruit tree economic forest in non-fruit tree economic forest coverage increased from 34.16% in 2012 to 41.24% in 2020, and the actual effective forest and grass vegetation coverage rate increased from 32.96% in 2012 to %57.86% in 2020. It is almost close to the forest and grass cover level of 59.14% in eastern Jinghe River basin. It shows that due to the continuous development of fruit industry in the whole basin, the planting area of fruit economic forest has been continuously expanded, which has greatly improved the actual and effective coverage degree of vegetation in the basin. The contribution rate of fruit economic forest to the vegetation coverage rate of forest and grass in the Hulu River Basin has increased from 19.09% in 2012 to 29.23% in 2020, but it has been ignored for a long time due to the nature of land use. At the same time, people also ignore the effect and influence of fruit tree economic forest on regional soil and water conservation and ecological

environment; At the same time, through monthly field observation, in-depth analysis of fruit tree economic forest cover on the basin scale of the underlying surface cooling, humidification, reduce wind speed, improve the microclimate of small watershed regulation and influence. So the climatological and ecological significance of watershed scale fruit tree economic forest as artificial vegetation cover was deeply explored and analyzed.

3.2.2. Mechanism of Sediment Reduction and Water Reduction Control Regulation

In the study of the influence of fruit tree economic forest on watershed scale mud and sediment retention and water reduction, Pearson correlation analysis method was used to deeply analyze the change of vegetation cover landscape pattern in the whole basin and the influence on watershed scale erosion control caused by fruit tree economic forest planting in the Hulu River basin. The quantitative relationship between the change of fruit tree economic forest cover and erosion factors was established, and the effect of fruit tree economic forest on sediment retention and sediment reduction at watershed scale and erosion control were deeply analyzed. The results showed that on the one hand, the root system improved soil structure, increased soil infiltration rate, increased soil water storage capacity, reduced runoff, and exerted an influence on water reduction control and regulation. On the other hand, by fixing plants and their canopy branches and leaves to intercept the flow, the surface runoff speed is slowed down and the ability of runoff to transport sediment is reduced, which is conducive to accelerating sediment deposition. At the same time, the sputtering erosion is reduced, the soil's anti-dispersion ability is enhanced, and the occurrence of rill erosion and inter-rill erosion is reduced, resulting in obvious sediment reduction control and regulation effects. Therefore, fruit tree economic forest cover has the effect of reducing erosion control on watershed scale runoff and sediment regulation.

3.2.3. The Ecological Function Quantity Index of Fruit Per Unit (1t) in Fruit Economic Forest Was Put Forward

In the analysis and research of fruit ecological function output per unit of fruit economic forest, this study analyzed the ecological function output per 1t of fruit produced by fruit economic forest in the Hulu River Basin as an important index to evaluate the relationship between ecological service function and social and economic function of fruit economic forest. The ecological function quantity per unit of fruit reflects the quantitative relationship between ecological service function and social and economic function of fruit tree economic forest, and the ecological function quantity per unit of fruit fully reflects the correlation between two different fields and nature variables of economy and ecology, that is, the ecological service value and ecological function quantity brought by fruit tree economic forest in the process of producing fresh fruits every year.

This study shows that the ecological functional quantities of fruit output per unit (1t) of fruit tree economic forest in the Hulu River Basin in 2020 are as follows: Water conservation $351.36m^3$, soil retention 294.97t, fertilizer conservation 31.27kg, carbon fixation 1.32t, oxygen production 3.54t, stand nutrient accumulation 0.13t, total purification 15.70kg (among them: Absorption of sulfur dioxide 13.07kg, absorption of fluoride 0.25kg, absorption of nitrogen oxide 0.85 (kg, dust fall 1.49kg), provide negative ions 2.16×10^{14}.

3.2.4. A New Idea and Method for Study on the Benefits of Forest and Grass Measures for Soil and Water Conservation

Through the evaluation methods and ideas of ecological service value adopted in this study, the economic benefits of soil and water conservation forest and grass measures can be calculated by water conservation value and soil conservation value. At the same time, the ecological function index of water conservation, soil conservation and fertilizer conservation was used to calculate the benefit effect of soil and water conservation forest and grass measures, and the carbon sink effect was calculated by carbon sequestration and oxygen release, which provided a new method and idea for further research on soil and water conservation effect and carbon sink in the future.

3.3. To Solve the Difficult Technology

(1) It solves the problem of actual and effective coverage statistics and calculation of forest and grass vegetation at watershed scale, and provides a new path and idea for future research on watershed ecological assessment, watershed carbon sink and soil and water conservation effect. By putting forward the concept index of the actual effective forest and grass vegetation coverage rate in the basin, this study breaks the restriction and constraint of land use nature and avoids the cover loss in the vegetation cover analysis and ecological assessment on the basin scale. In particular, it is of great scientific value for the ecological maintenance of ecologically fragile areas in arid and semi-arid Loess Plateau.

(2) To a certain extent, it solves the value exchange index problem in the process of realizing the value of ecological products. Through the research of ecological function service value of fruit tree economic forest, this paper puts forward the index of ecological service economy ratio, which can be used as one of the reference indexes of the value exchange of ecological products.

(3) The key technical path of watershed scale ecological security assessment is solved. By studying the ecological function service value and ecological function quantity of the fruit tree economic forest in the Hulu River basin, this study quantitatively studied the multiple overlapping functions and compensation effects of the fruit tree economic forest in land cover, vegetation cover, ecological economy, soil and water conservation, and ecological services in multiple dimensions. The huge ecological function output of the research has an important impact on improving the

ecological service capacity of the whole basin, improving the ecological structure of the basin, improving the ecological sensitivity of the basin, reducing the ecological vulnerability of the basin, enriching the biodiversity, and improving the vegetation landscape pattern, and has great significance and role in preventing soil erosion and building the ecological security of the whole basin. The study of the technical route will provide an important reference for ecological security assessment at small watershed scale in the future.

3.4. Innovation Points

3.4.1. Ecological Service Perception and Ecological Service Perception

This study proposed the concepts of ecological service perception and ecological perception, and took the ecological function amount of fruit per unit of fruit economic forest as the evaluation index of ecological service perception. The ecological function quantity of fruit per unit of fruit economic forest reflects the correlation between ecological and social economic fields and property variables, and is an important index to evaluate the relationship between ecological service function and social economic function of fruit economic forest. Its function is to perceive the ecological service value and ecological function quantity brought by the fruit economic forest in the process of producing fresh fruits by the smallest unit of fruit production or consumption, so as to improve the social public's more perceptual cognition and deeper understanding of the ecological service function of the fruit economic forest, that is, to improve the social public's perception of ecological services. Through the concept of ecological service perception, the public can deepen their understanding of the concept of protection priority and green development and change their lifestyle, and also provide support and reference for local governments to coordinate the relationship between ecological protection and economic development.

3.4.2. Eco-service Economy Ratio (GEP/GDP)

The concept and meaning of the eco-service economy ratio were first proposed, which refers to the ratio of the ecological function service value of the fruit tree economic forest to the annual output value of the same period, which is used to reflect the relative size of the two types of ecological and economic values. In the process of realizing the value of ecological products, it can be used as an important index of the value exchange of ecological products. In this study, the change range of eco-service economy ratio of fruit tree economic forest in the Hulu River Basin from 2005 to 2020 is 1.98 ~ 7.95, and 2.12 in 2020.

3.4.3. Actual Effective Forest and Grass Vegetation Cover

That is, the total area of forest and grass + the area of fruit tree economic forest, which is used to reflect the ecological significance and soil and water conservation effect of fruit tree economic forest on the actual effective cover of forest and grass vegetation in the loess hilly and gully region. In a broad sense, vegetation cover in the Hulu River Basin consists of crop cover and forest and grass cover. Due to the division of land use nature, fruit tree economic forest belongs to economic forest on agricultural land and is not included in the calculation range of forest and grass coverage rate in a region. However, as one of the main artificial economic forests in the loess hilly and gully region, fruit tree economic forest naturally has certain stand structure characteristics, and has the same soil and water conservation effect and ecological service function as soil and water conservation forest and other ecological public welfare forests in a certain planting cycle (such as 15-20a). Therefore, fruit-tree economic forest has become an important vegetation cover type in this region.

3.4.4. The Actual Effective Forest and Grass Vegetation Coverage Rate of the Basin (%)

The total area of forest and grass and the total area of fruit tree economic forest accounted for the percentage of the total land area (%), reflecting the actual and effective coverage degree of all forest and grass vegetation in the basin within a certain time. By putting forward a new concept of actual effective forest and grass vegetation coverage rate in the watershed, this project is conducive to analyzing the contribution rate and influence degree of fruit tree economic forest to the actual effective cover of forest and grass vegetation in the watershed scale. Therefore, for the vegetation cover in a specific area, the actual effective forest and grass vegetation cover should not be neglected due to the nature of land use, resulting in the loss of vegetation cover. (It is precisely because the lost fruit tree economic forest is used as effective vegetation cover that people ignore the functional role and impact compensation of fruit tree economic forest on watershed scale soil and water conservation and ecological environment).

4. Social and Environmental Benefits Achieved

4.1. Social Benefits

4.1.1. Improve the Public's Perception of Ecological Services

This study closely links the ecological service function of fruit economic forest with the social and economic function and lifestyle through the research of ecological function quantity of fruit per unit, so that the public can deeply perceive the ecological service value and ecological function quantity brought by the fruit economic forest in the process of producing fresh fruits each year through the smallest unit of fruit production or consumption. In particular, it is more direct and specific to people's perception of the ecological environment quality of the basin, which is widely concerned, and it can improve the public's more perceptual cognition and deeper understanding of the ecological service function of the fruit tree economic forest, so as to improve the public's perception of ecological services. The degree of ecological

service perception is conducive to the public's understanding of the concept of protection priority and green development and the change of life style.

4.1.2. Ecological Public Welfare

This study shows that a certain scale of fruit tree economic forest coverage in the loess hilly and gully region has changed the spatial pattern of land use, vegetation landscape pattern and soil erosion control pattern, greatly enhanced the continuity and ductility of the limited forest and grass vegetation, which is conducive to the conservation of species resources in the region, maintaining and enhancing the biodiversity of the region, and promoting the harmonious coexistence between man and nature. Due to the extreme importance of vegetation cover to ecological maintenance and soil erosion control in the ecologically fragile area of the Loess Plateau, the possible ecological public welfare loss caused by the adjustment of fruit tree economic forest must be considered first when adjusting the industrial structure.

4.2. Environmental Benefit

The comprehensive environmental benefit of this study is illustrated through the results of the research on ecological functional quantity and carbon sink of fruit tree economic forest. Taking 2020 as the year of environmental benefit calculation, the annual water conservation amount of fruit tree economic forest in the Hulu River basin in Pingliang City is 256,736,300 m^3, the soil consolidation amount is 215,536,500 t, and the fertilizer conservation amount is 22,846.87t (N: 1724.29t, P: 3233.05 t, K: 1508.76 t, soil organic matter: 16380.78 t), carbon fixation 965724.34t, oxygen release 2585403.66 t, stand nutrient fixation 93639.41 t (among them: N accumulation of 52577.11654t, P accumulation of 4127.955431t, K accumulation of 36934.33807t, purification of atmospheric environment function of 11470.85t (among them: The amount of sulfur dioxide absorbed is 9553.66t, the amount of fluoride absorbed is 181.05t, the amount of nitrogen oxide absorbed is 646.61t, the amount of dust fall is 1089.54t, the amount of negative ions provided is 1.5786×10^{24}), The biodiversity index of species resource conservation services reached grade 5 ($2\leq$Shannon-Wiener index < 3).

The output ecological functional quantities of each 1t fruit production were: water conservation 351.36m^3, soil conservation 294.97t, fertilizer conservation 31.27kg, carbon fixation 1.32t, oxygen production 3.54t, stand nutrient accumulation 0.13t, total purification 15.70kg (among which: Absorption of sulfur dioxide 13.07kg, absorption of fluoride 0.25kg, absorption of nitrogen oxide 0.85kg, dust fall 1.49kg), provide negative ions 2.16×10^{14}.

5. Promotion and Application Prospects

The research results of this project will provide a reliable theoretical basis and technical support for coordinating the relationship between regional agriculture and forestry, economic development and ecological protection, promoting the construction of a system governance system of mountains, rivers, forests, fields, lakes and grasslands in the loess hilly and gully region of Longzhong, and provide a reference for ecological protection and green, low-carbon and high-quality development of the Loess Plateau in the middle reaches of the Yellow River. The breakthrough of key technologies and the difficult problems solved can provide references for the research on the benefit effect of watershed scale soil and water conservation, the assessment of watershed ecological security, the research on watershed carbon sink, and the realization of the value of ecological products. The conclusions obtained from the research will provide support for local governments to coordinate the relationship between ecological protection and green and low-carbon economic development in the process of industrial structure adjustment. Therefore, the results obtained in this study can be applied in most areas of the Loess Plateau, especially in areas covered by concentrated and contiguous fruit trees.

6. Conclusion

The conclusion of this study is: In the loess hilly and gully region of Longzhong, a certain scale of fruit tree economic forest coverage has changed the regional (watershed scale) land use spatial pattern, vegetation landscape pattern and soil erosion control pattern, contributing to both GDP and GEP, and having multiple overlapping compensative effects on watershed scale soil and water conservation and ecology. It is extremely important for ecological maintenance and soil erosion prevention in the ecologically fragile area of the Loess Plateau, and its potential ecosystem service value and huge ecological function capacity for maintaining the ecological security of the basin cannot be ignored in the process of economic development. Therefore, when adjusting the industrial structure, it is necessary to first consider the huge ecological public welfare loss that may be brought about by the adjustment of fruit tree economic forest. The research results of this project will provide a reliable theoretical basis and technical support for coordinating the relationship between regional agriculture and forestry, economic development and ecological protection, promoting the construction of a system governance system of mountains, rivers, forests, fields, lakes and grasslands in the loess hilly and gully region of Longzhong, and provide a reference for ecological protection and green, low-carbon and high-quality development of the Loess Plateau in the middle reaches of the Yellow River of china.

ORCID

Wang Fu: 0009-0009-1833-7414
He Qian: 0009-0007-3393-9697
Zhao Qiang: 0009-0005-7534-5075
Sha Xiao Yan: 0009-0009-5732-8254
Han Fen: 0009-0000-3861-0582
Zhang He: 0009-0009-8480-5802

Conflicts of Interest

The authors declare that they have no competing interests.

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