International Scholars Journals

Advanced Journal of Microbiology Research ISSN 2241-9837 Vol. 13 (2), pp. 001-006, February, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

A study on the vegetation recovery and crop pattern adjustment on the Loess Plateau of China

H. Y. Fang[1], Q. Y. Li[2,3]* and Q. G. Cai[1]

[1]Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China. [2]Editorial Office of the Transactions of the Chinese Society of Agricultural Engineering, Chinese Academy of Agricultural Engineering, Beijing 100125, China [3]College of Water Conservancy and Civil Engineering, China Agricultural University, Beijing 100083, China.

Accepted 07 January, 2019

Low vegetation coverage and irrational land use are regarded as two main factors in influencing soil loss. In order to improve vegetation recovery and to adjust land use pattern on the Loess Plateau, the data of precipitation, net primary productivity of vegetation, and eco- water requirement of main crops of key counties on the Loess Plateau are used in this paper. The concepts of utilization/adaptation capability of eco-water requirement are used and plotted against mean annual precipitation in the 1960s to 1990s for vegetation and crops, respectively. Results demonstrate that in the regions with lower than 400, 400 to 510 and over 510 mm precipitation, the grass/shrub, grass/shrub/forest and forest fit to be planted, respectively. For crops in the regions with less than 300, > 310, > 450 and > 510 mm precipitation, Kaoliang and glutinous, millet, winter wheat, and maize are satisfied, respectively.

Key words: Loess Plateau, vegetation, crops, adaptation capacity eco-water requirement.

INTRODUCTION

Loess Plateau accounts for more than 40% of the territory in the Northwest region of China, soil erosion of which is amongst the highest (about 100 t ha^{-1} $year^{-1}$) in the world (Douglas, 1989; Tang et al., 1991; Pimentel, 1993; Derbyshire and Wang, 1994; Walling and Webb, 1996; Xu, 1999; He et al., 2006). Poor vegetation cover and irrational agricultural pattern are regarded as two main factors in influencing soil erosion in this region (Fu, 1989; Fu and Gulinck, 1994; Jiang, 1997; Chen et al., 2003; Zhang et al., 2004). Previous studies indicated that vegetation coverage is one of the important factors in controlling soil loss, and the amount of soil erosion decreases dramatically with the increase in vegetation coverage on the Loess Plateau of China (Shi and Shao, 2000; Zhang et al., 2004; Liu et al., 2005; Zhou et al., 2006). Van Dijk et al. (1996) found that appropriate measures of afforestation can reduce soil erosion by 40 to 60%. Hawley and Dymond (1988) reported that 100% tree cover reduces storm damage and landslides at least 70%. In Utah and Montana, as the amount of ground cover decreases from 100% to less than 1%, erosion rates increases by approximately 200 times (Trimble and Mendel, 1995; Pimentel and Kounang, 1998). Agriculture, as a principal economic activity on the Loess Plateau region (Zhang et al., 2004), increases with increasing population and farmland reclamation after the establishment of the People's Republic of China, which results in the acceleration of deforestation and tillage of grassland leading to larger soil erosion (Uri, 2001). In order to control soil erosion, the Chinese government, aided by the Chinese Academy of Sciences (CAS), formulated new ambitious policies about the Loess Plateau in 1999 to reduce farmland area (Hessel et al., 2003), and the fields above a certain slope degree should be changed from farmland to other uses to improve vegetation coverage (Hessel et al., 2003). Some studies also pointed out that the better-protected soil is beneficial to make vegetation recovery easier and to make the rain-fed agriculture sustainable development (Pimentel and Kounang, 1998; Chen et al., 2003; Zhang et al., 2004).

*Corresponding author. E-mail: lqymily@163.com

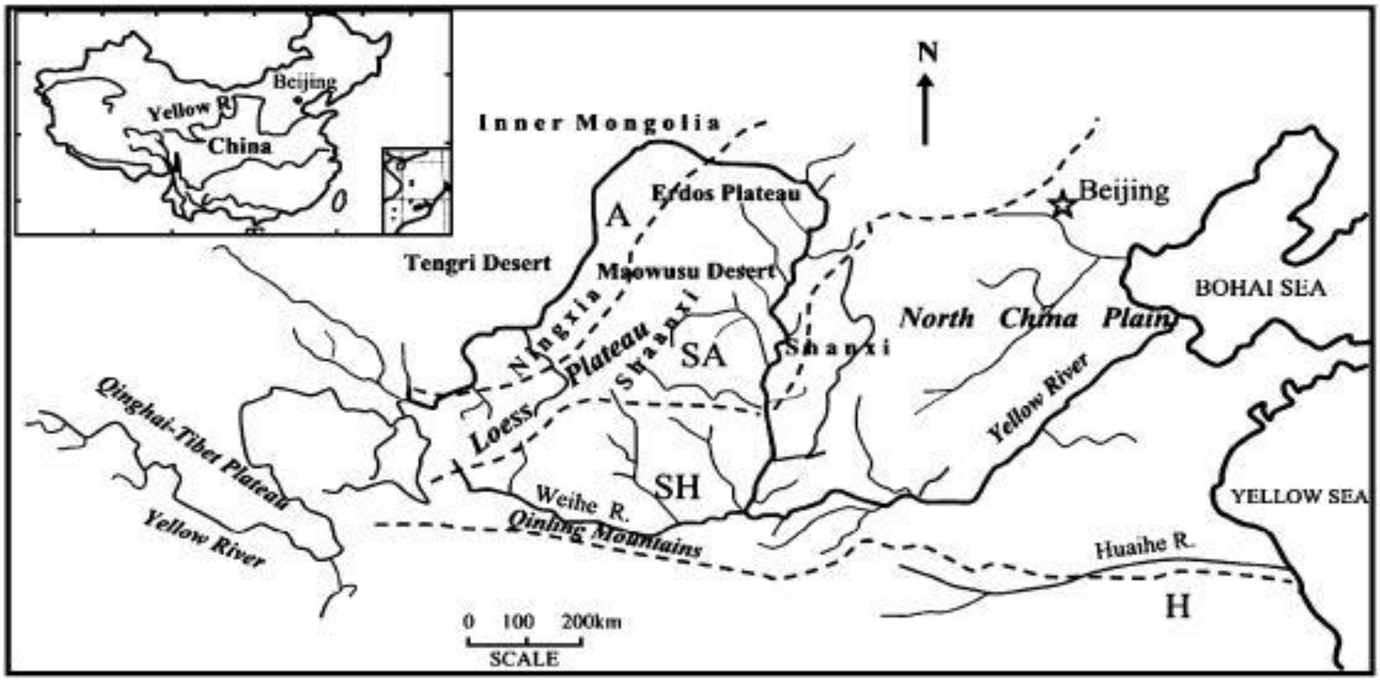

Figure 1. Map showing the study area. The dashed lines are boundaries between climates; A is arid climate, SA is semiarid climate, SH is sub-humid climate and H is humid climate. The boundary lines between humid, sub-humid, semi-arid, and arid climates are shown as isolines of the dryness index 1.0, 1.5, and 4.0. (modified from Xu, 2005).

Studies aforementioned indicate the importance of vegetation recovery and the adjustment of land use pattern in controlling soil loss on the Loess Plateau. However, papers on recovering vegetation and land use pattern adjustment on the Loess Plateau are scarcely documented. Therefore, the objectives of this paper are to direct the construction of vegetation recovery on the Loess Plateau and to adjust crop plantation pattern and composition in this region.

METHODOLOGY

Description of study area

The Loess Plateau of China, approximately 34 to 40°N, 110 to 115°E, 1000 to 1500 m asl, has an area of 285.9 thousand km^2 covering arid, semi-arid and sub- humid climate (Xu, 2005). The mean annual precipitation varies from 200 to 700 mm in the northwest to southeast direction, most of which occurs during June to September (Yang and Shao, 2000). In the same direction, natural vegetation types vary from arid desert, steppe to broad -leaf deciduous forest. A thick loess mantle covers the study area, and the grains size of loess becomes thinner categorized as eolian sand, sandy loess, typical loess and clayey loess from the northwest to southeast. Figure 1 is a Map showing the study area.

QUANTITATIVE INDICES AND DATA SOURCES

To quantitatively express the eco-water requirement of vegetation in the study area, apart from annual precipitation, some indices are introduced. Then, the relationships between these indices and precipitation are studied, thereby revealing the amount of eco-water requirement of vegetation and crops, and to guide the work of vegetation recovery and land use pattern adjustment on the Loess Plateau.

To test the water utilization status of vegetation to the precipitation in the study area, the concept of utilization capability of precipitation by vegetation (U) is used which is defined as net primary productivity (*NPP*, in $t\cdot ha^{-1}\cdot year^{-1}$) of vegetation divided by precipitation given in $t\cdot ha^{-1}\cdot year^{-1}\cdot mm^{-1}$.

$$U = NPP / P \quad (1)$$

Water is a decisive factor affecting the vegetation growth. Therefore, the change of vegetation eco-water requirement change is defined as *Q* expressed as follows:

$$Q = U_{\mathrm{h}} / U_r = (P_r \cdot NPP_h) / (P_h \cdot NPP_r) \quad (2)$$

where, U_r, NPP_r and P_r are utilization capability of precipitation by vegetation, net primary productivity, and precipitation in reference stage (before 1970s), respectively; U_h, NPP_h and P_h are utilization capability of precipitation of vegetation, net primary productivity, and precipitation since 1970s, respectively.

Adapting capability of eco-water requirement of farm crop (*W*) is defined as the ratio of natural precipitation to that of the farm crop in its growing term, expressed as follows:

$$W = P_{\mathrm{s}} / P_{\mathrm{x}} \quad (3)$$

where, P_s, the amount of precipitation in the growing stage of farm crop, and P_x, the amount of water requirement for crop in its growing stage.

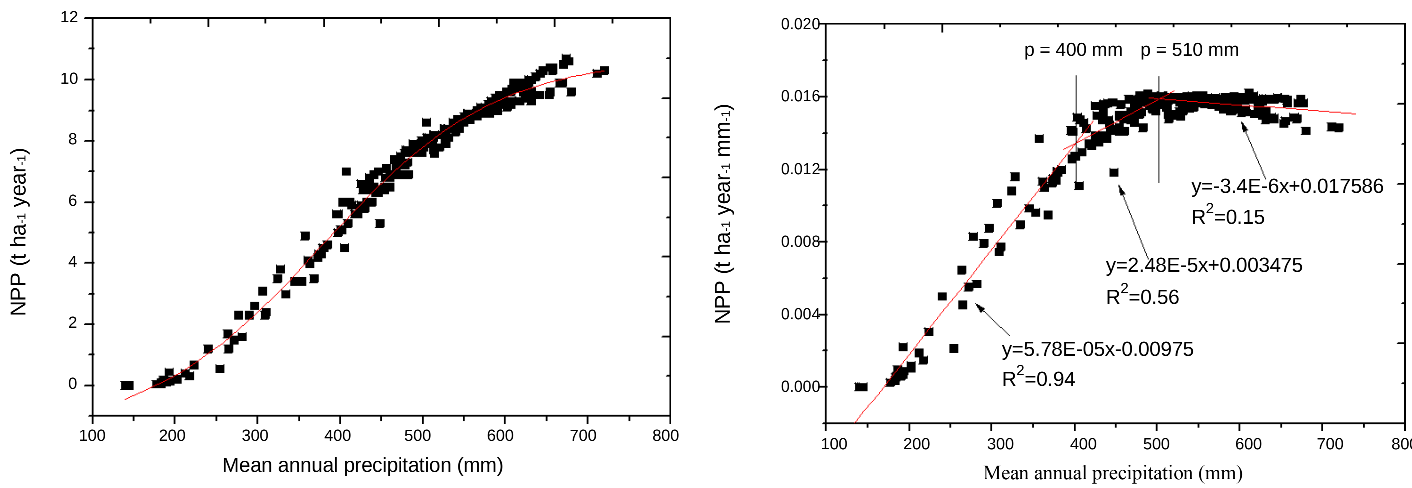

Figure 2. Relationship between mean annual precipitation and (a) net primary production (NPP), and (b) vegetation adaptation capacity of eco-water requirement.

The data net primary production (*NPP*) used herein are from Zhu (1993), who proposed a modified method to estimate *NPP*, and calculated the *NPP* values for ca. 300 counties on the Loess Plateau. Detailed calculating way sees the study by Zhu (1993). The precipitation and the amount of water requirement for crop in its growing stage (P_x) in this paper are from Integrated Scientific Research Team of Loess Plateau of the Chinese Academy of Sciences (1992).

The effects of precipitation and net primary production on the amount of eco-water requirement of vegetation and crops were analyzed using two-way ANOVAs in the treatments. Differences among means were assessed using Tukey's studentized range test.

RESULTS AND DISCUSSION

Vegetation construction

In reference stage (1960s)

Water is a decisive factor in respect of the primary productivity power of vegetation. Figure 2a shows a non-linear relationship exists between net primary productivity and means annual precipitation on the Loess Plateau. The table demonstrates net primary productivity of vegetation improves exponentially with increasing mean annual precipitation indicating the bio-natural zone must be accordance with natural precipitation (Liu et al., 2005).

According to the study by Chen et al. (2005) in the region on the Loess Plateau where precipitation is less than 400 mm, grass and shrub are appreciable; the region where precipitation is between 400 and 530 mm belongs to transition zone from grass/shrub to forest, and forest is appreciable in the region where precipitation is over 530 mm. Figure 2b demonstrates almost the same result as that by Chen et al. (2005). Utilization capability of precipitation by natural vegetation (U) increases abruptly with precipitation increase within 400 mm, slowly with 400 to 510 mm precipitation, while a little decreasing trend when precipitation is over 510 mm (Figure 2b).

Water is a crucial factor in determining vegetation growth on the Loess Plateau. He et al. (2003) pointed out mass mortality of infant plants or even mature trees in the artificial forest due to water deficit. The water deficiency for vegetation is, first because of less precipitation, which can not be changed by human power and the second reason, is the irrational figuration of grass/shrub/forest. Microscopically, the figuration of the three kinds of vegetation should firstly adhere to bio-climatic zone rule. Combined with the study by Chen et al. (2005) and Figure 4, in the region where the precipitation is lower than 400 mm, grass/shrub are appreciable; in the region where the precipitation ranges from 400 to 510 mm, the adaptation capability of vegetation changes little, and the precipitation satisfies the water requirement of grass and shrub; in the region where precipitation is over 510 mm, forest is suitable to plant. Secondly, afforetation is also subjects to the different location vertically in a given catchment (Kimura et al., 2005) . Thirdly, the selection of anti-arid grass/grass/forest type and the management for them also determine the vegetation recovery on the Loess Plateau. Because the growth of vegetation on the Loess Plateau mainly depends on the natural precipita-tion, to prevent and control soil erosion rational figuration of grass/shrub/forest is very important on the Loess Plateau.

Current stage (1970s to 1990s)

Regarding the utilization capability of eco-water require-ment (*U*) in 1960s as reference value unit (Q = U in 1960s), the *Q* values in the 1970s to 1990s for the key counties on the Loess Plateau are plotted in Figure 4, which demonstrates that the *Q* values in the 1970s are less than unit indicating water deficit appears comparable

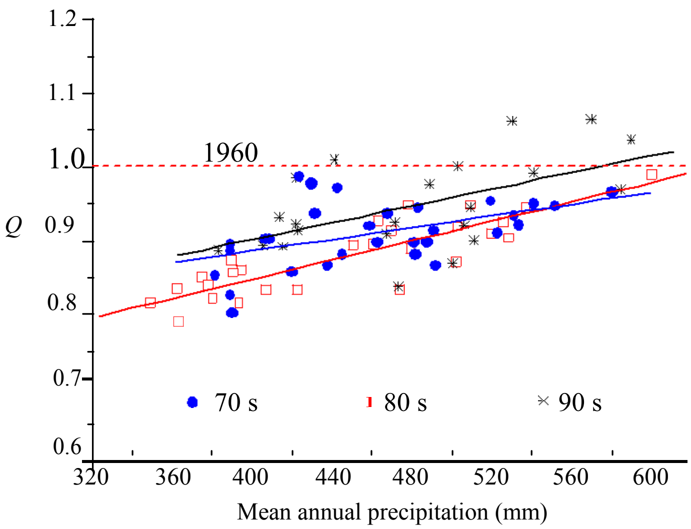

Figure 3. The relative changes of adaptation capacity of vegetation since 1970s to that in the reference term (1960s).

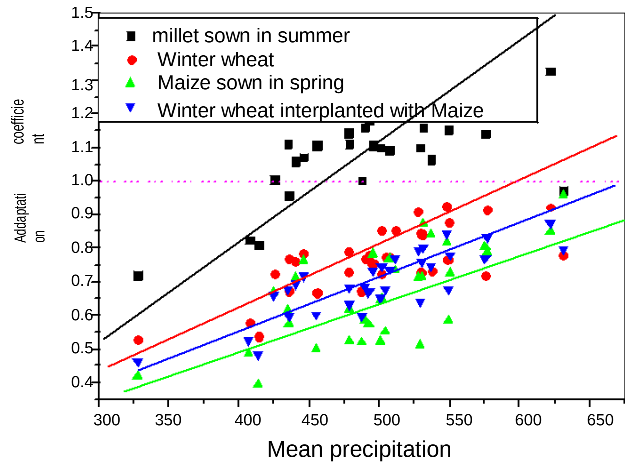

Figure 4. Relationship between mean precipitation and adaptation capacity of eco-water for main crops on the Loess Plateau.

to those in 1960s, and the status of water deficit is up to the greatest in the 1980s, though *Q* values in the 1990s present a little increase compared with those in the 1980s, almost all the *Q* value spots is still less than unit. Figure 4 tells us the reduction of precipitation leading to the water deficit for vegetation since 1970s is a crucial cause of lower living ratio of the planted grass/shrub/ forest on the Loess Plateau.

Figure 3 shows the relative changes of adaptation capacity of vegetation since 1970s to that in the reference term (1960s).

Crop eco-water requirement

Foxtail millet, glutinous millet, maize and Kaoliang are the main food crops; the sown area of which occupy 50% of the total area of food crops, and 90% of them are sowed on the arid land (Yang and Yu, 1992). Statistical data of the 36 key counties on the Loess Plateau shows that the adaptation capacity of eco-water requirement (*W*) of millet sown in summer, maize sown in spring, winter wheat and winter wheat interplanted with maize all positively correlate with precipitation in their growing stage. Furthermore, millet sown in summer in almost all the key counties is mostly satisfied with its eco-water requirement by natural precipitation (*W* 1); other crops, like winter wheat, maize sown in spring and winter wheat interplanted with maize sown in spring can not be satisfied with eco-water requirement, and the adaptation capability of eco-water requirement of maize sown in summer is the smallest one for the crops. Figure 4 and Table 1 shows millet sown in summer fits to be planted in the regions where precipitation is over 310 mm. Winter wheat fits to be planted in the > 450 mm precipitation regions, and maize in the > 510 mm precipitation regions, while winter wheat interplanted with maize in the > 480 mm precipitation regions. According to the study by Yang and Yu (1992), glutinous and Kaoliang should be planted in the other regions with less than 300 mm precipitation (Table 1). Figure 4 indicates that almost all the crops on the Loess Plateau can not satisfy the natural precipitation. Returning farmland to forest and grass or regulating the agricultural structure in arid sloping farmland is needed and millet sown in summer is appreciable in over 310 mm precipitation region on the Loess Plateau.

Before 1958, large amounts of soil on the Loess Plateau were reclaimed for farmland, even on steeper sloping surface (Chen et al., 2003). For repeatedly tillage, the steeper farmland can lead to large erosion, and should be converted to natural vegetation. The irrational plantation just leads to low productivity per unit area of farmland with not high total crop outcome. Large amount of irrational farmland reclamation results in severe soil loss (Chen et al., 2003). While in the farmland where the water is enough with not larger slope degree, such as crops planted on dam-land, the productivity capacity per unit area farmland is highly improved, which is tenfold of those of the irrational farmland, and the total crop outcome is not lower or higher than before. The study by Zhang et al. (2004) in Zhifanggou catchemt verifies above viewpoint.

Relationships of vegetation recovery, farmland and soil erosion

Studies mentioned previously demonstrate the great contribution of vegetation to fighting against soil loss, and vegetation recovery, especially on steeper sloping surface is suggested a good way to reduce soil loss on the Loess Plateau (Chen et al., 2003; 2004; Zuazo et al.,

Table 1. Eco-water requirement of main crops planted on the Loess Plateau.

Type	Millet[a]	Maize[a]	Winter wheat[a]	Winter wheat + maize[a]	Kaoliang[b]	Glutinous[b]
Eco-water requirement (mm)	310	508	448	480	<300	<300

[a]represents data from Integrated Scientific Research Team of Loess Plateau of the Chinese Academy of Sciences (1992), and [b]from Yang and Yu (1992).

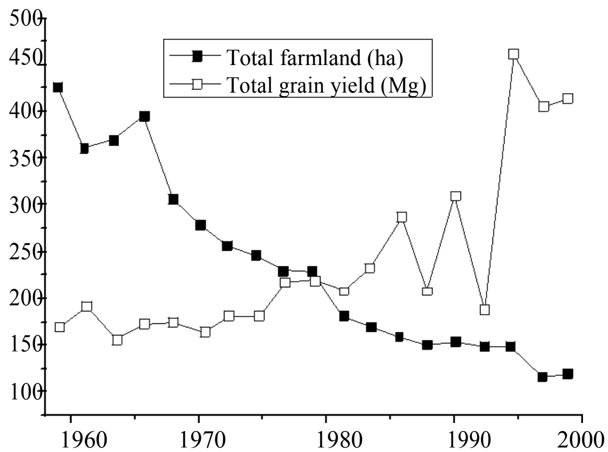

Figure 5. Change of the total farmland area and grain yield in Zhifanggou watershed (a small watershed of Loess Plateau) from 1958 to 2000 (Zhang et al., 2004).

2004). Though farmland reduces for some of them are converted vegetation construction, the improved productivity capacity per unit area for farmland makes up for it, and the total crop yield does not decrease or even increase Figure 5. Farmland is more highly susceptible to erosion because it is tilled repeatedly, the tense erosion on which is estimated to be 75 times greater than that occurring in natural forest areas (Pimentel and Kounang, 1998). Soil erosion makes large amounts of soil loss, which is regard as a major cause of the deforestation now taking place throughout the world (Pimentel and Kounang, 1998). For the soil loss accompanying with nutrient loss, about 30% of the world's farmland has become unproductive and, therefore, has been abandoned by humans (Lal, 1990, 1994). So, the higher the vegetation coverage is, the less the soil is eroded away, and the higher the farmland productivity capacity improves.

Conclusions

Poor vegetation coverage and irrational land use are regarded as two main factors in influencing soil loss on the Loess Plateau of China, and both of them is to a great extent determined by precipitation. In this paper, with derived indices, such as U , Q, and W, and some studies by others, the vegetation construction and crops' plantation were discussed on the Loess Plateau given different precipitation ranges, and the conclusions were obtained:

1. In the region where the precipitation is lower than 400 mm, grass/shrub are appreciable; in the region where the precipitation ranges from 400 to 510 mm, the precipitation satisfies the water requirement of grass/shrub/forest; and in the region where precipitation is over 510 mm, forest is suitable to plant.
2. For crops' plantation on the Loess Plateau, in the region where precipitation is less than 300 mm, Kaoliang and glutinous should be planted; in the region where precipitation is over 310 mm, millet is suggested; winter wheat fits to be planted in the > 450 mm precipitation regions, and maize in the >500 mm precipitation regions, while winter wheat interplanted with maize in the > 480 mm precipitation regions.

ACKNOWLEDGEMENT

The authors wish to acknowledge the projects of the National Grand Fundamental Research 973 Program of China under Grant No. 2010CB428404, the Open Fund of Key Laboratory of Yellow River Sediment Research of the Ministry of Water Resources (Grant No. 2010007) and the Special Foundation of President of the Chinese Academy of Sciences for their financial support of this work.

REFERENCES

Chen L, Messing I, Zhang S, Fu BJ, Ledin S (2003). Land use evaluation and scenario analysis towards sustainable planning on the Loess Plateau in China-case study in a small catchment. Catena, 54: 303-316.

Chen H, Liang GL, Zhou JX, Cai QG, Lu ZC, Huang JG (2005). Influence of vegetation recovery on sediment yield and vegetation recovery prospect in the middle reaches of Yellow River. Sci. China Ser. D, 35: 452-463.

Chen H, Tsui Y, Cai QG, Tham LG, Hu WS, Yue ZQ, Huang JG (2004). A study of morphological relationships between hillslope and gullies: taking small catchment of Wangjiagou in Shanxi Province as a case. Geogr. Res., 21: 329-338.

Derbyshire E, Wang J (1994). Cast study of human impact: China's Yellow River basin. In Roberts N. (eds.) The changing global environment. Blackwell, Oxford, England, pp. 100-111.

Douglas I (1989). Land degradation, soil conservation and the sediment load of the Yellow River, China: review and assessment. Land Degrad. Rehabil., 1: 141-151.

Fu BJ (1989). Soil erosion and its control in the Loess Plateau of China.

Soil Use Manage., 5: 76-82.
Fu B, Gulinck H (1994). Land evaluation in the Loess Plateau of sever erosion: the Loess Plateau of China. Land Degrad. Rehabil., 5: 33-40.
Hawley LG, Dymond JR (1988). How much do trees reduce landsliding? J. Soil Water Conserv., 43: 495-498.
He XB, Li ZB, Hao MD, Tang KL, Zheng FL (2003). Down-scale analysis for water scarcity in response to soil-water conservation on Loess Plateau of China. Agric. Ecosyst. Environ., 94: 355-361.
He XB, Zhou J, Zhang XB, Tang KL (2006). Soil erosion response to climatic change and human activity during the Quaternary on the Loess Plateau, China. Environ. Change, 6: 62-70.
Hessel R, Messing I, Liding C, Ritsema C, Stolte J (2003). soil erosion simulations of land use scenarios for a small Loess Plateau catchment. Catena, 54: 289-302.
Integrated Scientific Research Team of Loess Plateau of the Chinese Academy of Sciences (1992). Resource and environment and socio-economic dataset on the Loess Plateau. Beijing: Chinese Economy Press., pp. 179.
Jiang D (1997). Soil erosion and control models in the Loess Plateau. China Hydroelectricity Press, Beijing, China.
Kimura R, Liu Y, Takayama N, Zhang X, Kamichika M, Matsuoka N (2005). Heat and water balances of the bare soil surface and the potential distribution of vegetation in the Loess Plateau. J. Arid. Environ., 63: 439-457.
Lal R (1990). Soil erosion and land degradation: the global risks. In Lal, R., Stewart, B.A., (eds.). Soil degradation. New York: Springer-Verlag, USA.
Lal R (1994). Water management in various crop production systems related to soil tillage. Soil Tillage Res., 30: 169-185.
Liu WG, Yang H, Cao YN, Ning YF, Li L, Zhou J, An ZS (2005). Did an extensive forest ever develop on the Chinese Loess Plateau during the past 130 ka? a test using soil carbon isotopic signatures. Appl. Geochem., 20: 519-527.
Pimentel D (1993). World soil erosion and conservation. Cambridge University Press, Cambridge.
Pimentel D, Kounang N (1998). Ecology of soil erosion in ecosystems. Ecosystems, 1: 416-426.
Shi H, Shao MA (2000). Soil and water loss from the Loess Plateau in China. J. Arid Environ., 45: 9-20.
Tang K, Zhang P, Wang B (1991). Soil erosion and eco-environment changes in Quaternary. Quaternary Res., 4: 49-56.
Trimble SW, Mendel AC (1995). The cow as a geomorphic agent: a critical review. Geomorphology, 13: 233-253.
Uri ND (2001). Then environmental implications of soil erosion in the united states. Environ. Monit. Assess., 66: 293-312.
Van Dijk PM, Kwaad FJPM, Klapwijk M (1996). Retention of water and sediment by grass strips. Hydrol. Proc., 10: 1069–1080.
Walling DE, Webb BW (1996). Erosion and sediment yield: a global review. IAHS Publ., 236: 3-19.
Xu JX (1999). Erosion caused by hyperconcentrated flow on the Loess Plateau of China. Catena, 36: 1-19.
Xu JX (2005). Precipitation-vegetation coupling and its influence on erosion on the Loess Plateau. Catena, 64: 103-116.
Yang W, Shao M (2000). Study on the soil water in the Loess Plateau. Science Press, Beijing, China.
Yang W, Yu CZ (1992). Comments and controlling of catchemts on the Loess Plateau. Science Press, Beijing, China.
Zhang B, Yang YS, Zepp H (2004). Effect of vegetation restoration on soil and water erosion and nutrient losses of a severely eroded clayey Plinthudult in southestern China. Catena, 57: 77-90.
Zhang QJ, Fu BJ, Chen LD, Zhao WW, Yang QK, Liu GB, Gulinck H (2004). Dynamics and driving factors of agricultural landscape in the semiarid hilly area of the Loess Plateau, China. Agric. Ecosys. Environ., 103: 535-543.
Zhou ZC, Shangguan ZP, Zhao D (2006). Modeling vegetation coverage and soil erosion in the Loess Plateau Area of China. Ecol. Model., 198: 263-268.
Zhu ZH (1993). A model for estimating net primary productivity of natural vegetation. Chin. Sci. Bull., 38: 1913-1917.
Zuazo VHD, Martínez JRF, Raya AM (2004). Impact of vegetation cover on runoff and soil erosion at hillslope scale in Lanjaron, Spain. Environmentalist, 24: 39-48.