地理学报(英文版) 2002年第12卷第4期

Erosion response to anthropogenic activity and climatic changes during the Holocene

作者: HE Xiubin TANG Keli

Soil erosion assessment and prediction play critical roles in addressing problems associated with erosion control or soil conservation. The past dynamics of soil erosion can provide valuable information for us to understand the relations of soil erosion to environmental change and anthropogenic activity. The present paper has compared Holocene climatic changes in northwestern China with those in southern Norway, and investigated the past dynamics of erosion activity during the Holocene. Modern soil erosion on the Loess Plateau is a combination of the intensive natural erosion and human-induced erosion, the latter being four times greater than the former. Because of global warming and increasing human activities, climate on the Loess Plateau is becoming dryer and more unstable, causing an enhanced erosion problem and water scarcity. In the arctic-alpine region of southern Norway, however, the global warming and regional wetting caused expansion of the largest European ice cap. This has accentuated the erosion in that region, with a higher frequency of avalanches and debris flows.

HE Xiubin1,2, TANG Keli1, John A Matthews3, Geraint Owen3 (1. Institute of Soil and Water Conservation, CAS, Yangling 712100, China; 2. Northwest SCI-Tech University of Agriculture and Forestry, Yangling 712100, China; 3. Department of Geography, University of Wales Swansea, UK) 1 Introduction Erosion has been an important drive to land surface processes throughout Earth history. In addition to causing on-site loss of topsoil and reducing the productivity of the land, modern soil erosion brings about major offsite environmental effects. Furthermore, flood, drought, and famine related soil erosion can be considered not merely as natural disasters, but also as cultural catastrophes, threatening global food and environmental security, especially in the developing countries (e.g. Morgan, 1995; Cai et al., 1999). Soil erosion assessment and prediction play critical roles in addressing problems associated with erosion control or soil conservation (e.g. Liu et al., 1999). In evaluating modern soil erosion and predicting soil erosion under condition of global change and population growth, we face a number of questions that can only be answered through a better knowledge of the past. Rate of soil erosion on the Loess Plateau of China is among the highest in the world (annually about 100 t/ha). A large population (82 million in area of 60 million ha) faces a major challenge of water and food security in a vulnerable environmental context. Evidence suggests that the climate is becoming dryer and much more unstable because of both global warming and intensive human activities, causing increasing problems of erosion and water scarcity (e.g. Jing et al., 1983; Tang Keli et al., 1991). In contrast, in arctic-alpine regions, global warming is associated with increased regional wetting. In southern Norway, the Jostedalsbreen ice cap (the largest ice cap on mainland Europe) and associated glaciers have expanded since the early 1980s due to increased precipitation (Nesje, 1995; Glasse, 1998). This has caused an increase in rates of erosion and deposition in regions adjacent to the glaciers, characterized by higher frequencies and magnitudes of avalanches and debris flows. The investigation of evidence from the past and monitoring the future trends are critical to an understanding of the mechanisms behind these phenomena. The present paper intended to compare Holocene climatic changes in northwestern China with those in southern Norway, and investigated the past dynamics of erosion activity in the past 10,000 years. 2 Rationale The loess sequence of northwestern China, characterized by alternations of silty or sandy loess with more clay-rich paleosols, and the deposits in Norwegian valleys characterized by alternations of organic peat layer interbedded with minerogenic layers (silt to boulder grade), record not only climatic changes, but also the past changes in rates of erosion and deposition. The Loess Plateau in the middle reaches of the Yellow River was the cradle of the ancient Chinese civilizati on. The thousands of years of agricultural history and very large-scale modern activities to guarantee food security have close links with the local environmental changes. This has provided a basis for investigating and monitoring the anthropogenic responses to regional land surface change, climatic change and even global change. Areas around the Norwegian glaciers with lower population density and less intensive human activities provide a basis for investigating and monitoring natural land surface change and its response to climatic change. 3 Results 3.1 Comparison of Holocene climatic changes Regional comparison of climatic changes is a basic key to understanding global climatic dynamics. The terrestrial archives of loess profile (e.g. Liu, 1985) and moraine stratigraphy (e.g. Matthews and Caseldine, 1987) combined with historic records give proxy evidence of climatic changes in regional individuals. Figure 1 demonstrates the Holocene climatic change comparison between the Loess Plateau of northwestern China and Jostedalsbreen of western Norway. Glacier fluctuation is in response to mean ablation-season temperature in summer (May 1-September 30) and winter precipitation in arctic-alpine region. Therefore, a history of glacier variations can sensitively reflect climatic change in southern Norway (Dahl and Nesje, 1996; Matthews et al., 2000; Nesje and Matthews et al., 2001). Figure 1 shows that the major climatic event in the Holocene, the Little Ice Age, was recorded simultaneously in Norway and China by both terrestrial and historic evidence. Another major climatic event, the Middle Holocene Climatic Optimum, occurred earlier in Norway (ca. 8000 cal. yrs BP). The Finse event and the Erdalen event recorded in the early Holocene in Norway have not been found in the loess profile so far; while the well recognized an abrupt cold and dry event in China around 3000 cal. yrs. BP is not recognized as a glacier advance in Norway. 3.2 Erosion dynamics during the Holocene On the Loess Plateau, with the climatic fluctuation, the processes of loess deposition, soil formation and soil erosion were nonstop throughout the Quaternary, but they acted as alternating predominant processes, thus forming today´s Loess Plateau and the special loess erosion geomorphologic landscape on the underlying ancient landform (e.g. Liu et al., 1985). In the past 2.5 million years, the Loess Plateau has been subjected to eight episodes of intensive natural erosion (He, 1999). With the inception of human beings, particularly with rapid growth of population, the activities of people have begun to affect our environment on a scale comparable with powerful natural processes, and the soil erosion system is not exclusively affected by anthropogenic factors. Table 1 shows that modern soil erosion is four times greater than the geological normal erosion rate. In southwestern Norway, there was relatively high debris flow activity between 4,000 and 2,800 14C yrs BP due to high frequency of climatic fluctuations at the same time as glacier advance (Figures 1 and 2). Recently, western Norwegian glaciers have expanded (Nesje, 1995; Glasse, 1998). This has speeded up the erosion-deposition process in that regions, characterized by high frequencies and magnitude of avalanches and debris flow activity in front of the glaciers. 3.3 Water scarcity in north—western China due to global warming and population growth To control the most serious soil erosion of the world and to guarantee food security for the local people on the Loess Plateau of China, we have been struggling to plant trees and grass, to implement tillage and dryland farming techniques, and to build terraces and dams in the past century. Great progress has been made in erosion control and food production since the 1980s. About 24% of the eroded area has been controlled (e.g. Li, 1997). Grain yield has increased greatly and sediment in the Yellow River has decreased by about 25% (Zhang, 1999). However, advancing sustainable development further, or even maintaining the current situation, will be a great challenge facing the increasing water scarcity on the Loess Plateau due to the burgeoning socio-economic development of the area combined with global climatic change. It is very important to understand this issue fully in order for strategic use of the limited water resources (ESD-CAS, 2001). There are many papers and reports analysing the origin causes of this running-dry phenomena from various aspects of water consumption by agricultural, residential and industrial sectors, hydraulic projects and climatic change as well (Derbyshire and Jingtai, 1994; Runshan, 1997; Brown and Halwei, 1998). The precipitation in the last two decades fluctuated around the average value of 500 mm, and will keep the similar in the near future (Figure 2). Meanwhile the runoff in the Yellow River has decreased from 3.8×1010 m3 before 1989 to 2.0×1010 m3 in the past ten years and would be about 1.0×1010 m3 in the near future. It means that climatic change did not play a key role and will not either in the near future as it is forecasted. As more than 98% of the runoff in the Yellow River comes from the middle (43%) and upper (55%) reaches and agricultural consumption of water usually accounts for more than 80% of the total consumption (Renqiong, 1998) according to traditional analysis. The soil-water-conservation-based agriculture on the Loess Plateau can thus play an important role on the water level fluctuation of the Yellow River. 4 Conclusions Because of global warming and increasing human activities, the climate on the Loess Plateau is becoming dryer and more unstable, causing an enhanced erosion problem and water scarcity. In the arctic-alpine region of southern Norway, however, the global warming and regional wetting seem to be going hand in hand, causing expansion of the largest European ice cap. This has accentuated the erosion in that region, with a higher frequency of avalanches and debris flows. Modern soil erosion on the Loess Plateau is a combination of th

e intensive natural erosion and human-induced erosion, the latter being four times greater than the former. Accurate assessment of modern erosion and prediction of future erosion are unfortunately limited by a lack of systematic data or a synthetic method for multi-scale data modeling. An agent-based simulating model on SWARM platform is being developed. Great progress has been made in erosion control and food production since the 1980s. About 24% of eroded area has been stabilized. Grain yield has increased greatly and sediment in the Yellow River has decreased by about 25%. However, advancing sustainable development further, or even maintaining the current situation, will pose great challenge given the burgeoning socio-economic development of the area combined with global climatic change.

关键词： anthropogenic activity; China; climate changes; erosion response; Norway

