地理学报(英文版) 2001年第11卷第3期

The impacts of urbanization on soil erosion in the Loess Plateau region

作者: SUN Hu et al.

Abstract: The accelerated urbanization has resulted in new soil erosion in the Loess Plateau region since the 1980s. A concept of urban erosion and its impacts on environment are discussed. The experimental studies and field investigations show that those loose silt and earth piles formed by urban construction can be eroded seriously: Under stormy rain, the amount of sediment from steep man-dumped slope is 10.8-12.2 times that of from uncovered slope land; the result of experiments with the wind tunnel also shows that the damage to the surface structure of dry loess can cause serious soil erosion by wind in some cities of the region. Even if in the urban built-up area, there are many loose sandy soil, mud and silt, which are washed into rivers by city´s ground flow in the rainy season. So, anthropogenically induced soil erosion has made soil erosion more serious around the urban areas. And the urban eroded environment has several characteristics such as fragility, complexity, seasonality and quick variability. Urban areas witness a quick economic growth and have more construction projects than rural areas, which brings more intensive changes of environments during a short period of time or adds some new elements to the erosion system. Therefore erosion has experienced more intensive impact by human activities. So, the possible impact of urbanization on erosion environment must be taken into consideration when designing or planning to exploit natural resources or to develop urban areas in the Loess Plateau.

The impacts of urbanization on soil erosion in the Loess Plateau region SUN Hu, GAN Zhi-mao, YAN Jun-ping (Department of Geography, Shaanxi Normal University, Xi´an 710062, China) 1 Introduction The Loess Plateau region covers an area of 62.4(104 km2 and lies in the center of northern China. Urbanization and economic development have been quickened in recent decades. Both the number of towns established and scale of cities have increased. Although the pace of urbanization has been accelerated, the eco-environmental control in urban areas still lags behind relatively. Moreover, the construction and development of cities damaged the already vulnerable eco-environment to some extent, thus resulting in further environmental deterioration in urban built-up area, development area and marginal area[1-5]. This amplifies the erosion problems in the Loess Plateau region. So, urbanization is facing a new environmental issue: soil erosion accelerated by economic development. According to the Map of Soil Erosion Types and Intensity of the Loess Plateau Region (1:500,000)[6], the 57 established cities (having a central distance of 15 km to downtown) cover 4.03 (104 km2, which account for 6.5% of the region´s total. However, the annual erosion amount is about 2.13(108 t/a, accounting for 13.3% of the annual average silt transported by the Yellow River (16(108 t). This shows that erosion is much more serious in cities and suburban areas than rural areas which are far away from cities. This paper aims to describe the characteristics and the constituents of urban erosion environments in the Loess Plateau region, and to provide scientific basis for soil erosion control, environmental improvement and healthy development of urbanization in the region. 2 Current situation of urbanization In the Loess Plateau region, urbanization has accelerated since the 1980s due to economic development, industrialization and exploitation of natural resources such as coal, oil and natural gas. There were 36 established cities in 1985 with a total population of 17.054 million, which was 20.8% of the region´s total. Of which urban non-agricultural population was 11.523 million, or 67.6% of the urban total and 14.15% of the region´s total. In the last 12 years, the number of cities increased to 57 by 1997 (Tables 1 and 2), with a total population of 33.691 million, accounting for 37.3% of the corresponding population of this region. Urban population rose to 17.317 million then, which was 51.4% of the urban total or 19.2% of the region´s total. Table 1 Population

s of different periods in the Loess Plateau region (1995, 1997) Table 2 Number of cities in the Loess Plateau region (1997) Including central area and suburbs, but not suburban counties, the urban built-up area and suburban area on the Loess Plateau region is 84519 km2, which is 13.6% of the region´s total. However, the central urban area is only 1819 km2, 2.2% of the total urbanized area. Both the central urban area and its population are relatively small compared to that of the suburbs. With the progress of urbanization, various kinds of infrastructure construction in cities are quickened, and the built-up areas got constantly expanded. For example, in Shanxi Province, urban built-up area expanded from 505 km2 in 1994 to 557 km2 in 1997. In Yulin of Shaanxi Province, urban built-up area expanded from 8 km2 to 15 km2 in the past 10 years. In Yan´an, urban built-up area expanded from 7 km2 in 1987 to 12 km2 in 1998. Urban expansion and infrastructure construction were completed by digging and moving soil and rock mass, leaving lots of abandoned loose earth and residues which were easily eroded by wind or water. Based on investigations to 17 places in Yan´an such as Yangjialing, North Railway Station, Lanjiaping, Qiaoergou etc. carried out from May 1997 to May 1998, the authors found that generally the erosive modulus of anthropogenic induced loose materials mostly ranged between 0.8(104 t/km2(a to 5(104 t/km2(a. Soil erosion of wasted slopes by man and steep slopes of man-made piles or side of platforms are most serious, whose erosive modulus are between 2.15(104 t/km2(a and 13.1(104 t/km2(a. By 1998, piles of loose solid materials artificially produced in Yan´an amounted to 1702.57(104 m3. The side effects of urbanization accelerated in the Loess Plateau region are as follows: urban infrastructure created loosely piled up materials increased greatly, all kinds of industrial solid materials were seen everywhere, sewage without being disposed drained into rivers randomly, urban runoff increased in rainy seasons which caused waterlogging and silt transfer; the coverage of forests and grass decreased in suburban and marginal areas, geologic and geomorphologic disasters such as landslides, debris flows increased. As a result, the deteriorated urban environment caused soil erosion being even more liable to occur. 3 Urban erosion environment It is useful to give a brief description of the terminology before discussing urban erosion environment. A city in the Loess Plateau region physically consists of a central urban area (A), outskirts (B), and outer suburbs (C) surrounded by rural areas (D) (Figure 1). The size of a city is controlled by its development history, resources, and administrative management levels. In the Loess Plateau region it has four levels of administrative divisions: province, prefecture, county, and township. So there are four levels of cities: provincial and prefectural capitals, county seat cities, and towns. In this paper we define an urban erosion environment as the conditions that influence soil erosion in urban and suburban areas of cities equal to or higher than county seat. Its physical limit consists of a central area, outskirts of the city and suburbs. Sizes of the suburbs depend on influences of cities. Metropolitans and medium-sized cities have suburbs and outer suburbs and are surrounded by rural areas. The suburban area is a transitional zone from urban to rural areas. There is a transitional zone from urban to suburban areas or from suburban to rural areas without demarcations between different areas. Therefore, urban erosion environment in this paper refers to both urban and suburban areas. The urban soil erosion environment is a system including erosion agents, loose materials and influential factors. Agents of urban erosion environments include water erosion, wind erosion, gravity erosion, and anthropogenic erosion (Figure 2). The sources of eroded materials include original surface deposits, external materials, wastes, temporary piles of soils and other washout silty-muddy materials. The contributing factors that influence the magnitude of the erosion problem include topographical conditions, vegetation type and cover, and permeability of surface deposits and constructions. It is the interaction of these erosive agents with the source materials and the influential factors that determine the environmental problems associated with urbanization. Figure 2 Composition of urban erosion environments 4 Characteristics of urban erosion environment 4.1 Fragility of urban erosion environment The Loess Plateau lies in the transitional zone from monsoon climate to inland non-monsoon climate, where it has a stormy summer and autumn and a windy winter and spring, and annual precipitation is less than 500 mm with frequent droughts. Except for some mountainous areas, most of the region has sparse vegetation coverage. Wind blown sand encroachment hazards occur in the vicinity of the Great Wall to the northern Loess Plateau. In addition to the broken hilly-gully land surface, loose loess deposits are the dominant surface materials in the southern region. These cause serious water erosion, wind erosion and sediment depositional problem. Sometimes the hyper-concentrated flows develop with stormy rain in rivers[7]. Therefore, the natural environment of the Loess Plateau is fragile, with little capacity in resisting natural hazards. Distributions and intensities of soil erosion in a suburban area will be influenced and controlled by the macro-scale environmental conditions. There are 13 cities in the northern arid and semi-arid wind-blowing sand area of the Loess Plateau, where wind erosion and water erosion are major problems. Provincial capital cities in this area are as Yinchuan and Hohhot. In semi-arid and semi-humid loessic hilly-gully, Loess Plateau hilly-gully, and rocky mountain areas there are 32 cities such as Lanzhou, Taiyuan etc. There are 12 cities in the southern semi-humid plain area such as Xi´an etc. Most of the cities (79%) are locate

d in the environments where wind and water erosion are major problems (Table 3). Table 3 Environmental conditions of cities in the Loess Plateau (1998) If the ground is disturbed by human factors, the surface soil will become easily t o be eroded by wind and water because of its loose structure and strong agents. The experiments with wind tunnel wer e carried out in Lanzhou Institute of Desert, CAS. The set of erosion experiments with wind tunnel divided into 5 gro ups was done for 25 times. The result shows that there is serious wind erosion about anthropogenic dry loess (Tables 4 and 5). That is to say the damage to the surface structure of loess can cause serious soil erosion by wind in some cities of the Loess Plateau. We have come to the conclusion with the experiments that Professor Qian Ning[8] earlier noticed erosion conditions of disturbed loess in the Loess Plateau. Table 4 Erosion ratio of loose loess under differ ent conditions of wind force (1998) Table 5 Relationship between wind erosion rate and moisture content of loose loes s 4.2 Complexity of urban erosion environments The erosion environment of urban areas is more anthropogenically distu rbed than that of rural areas. In sparse populated rural areas erosion is predominantly natural, although economic ac tivities exert influence on the environmental processes. Owing to urbanization, economic activities strongly impact u rban environments. Erosion processes, erosion agents, surface resistance properties, and other factors are more compl icated and dynamic than in rural areas (Table 6). In urban areas, the erosion environment has been changed with or af ter constructions to a great extent. First, human activities not only remove and disturb natural stratum, but also ma ke the erosion agents affect loose ground surface more easily. Second, the natural and human agents can interfere eac h other, especially make the gravity factor more active. Third, a lot of loose materials dumped on construction site s, and at the same time forming many steep slopes by digging ground surface. So, the eroded environment has been grou ped into many different small environmental areas in cities. Table 6 Difference between rural and urban environments 4.3 Intensive human impact There exists a so-called "natural land surface" in urban areas. All surfaces are disturbe d by economic activities. Most urban areas have man-made environments, landscapes and surface. The lands have been ch anged to buildings, roads, and brick-gravel pavement surface. Construction sites like roads, buildings, and many of p ipelines may have earth and gravel piles that are not rationally covered. Irrationally piled waste soils, residues an d gravels can be seen everywhere. Intensive farming complicates the erosion environmental processes. For example, fe w natural rivers can be found in cities of the Loess Plateau. Land use types are vegetable production, industrial sit es, residential areas, communications and other urban installations with less green surfaces or woods in Xi´an (Tabl e 7). Table 7 Land use in the suburban area of Xi´an+ (1995) Populations and cultivation levels in some cities in hil ly areas of the Loess Plateau decrease while vegetation coverage increases from the central area of the cities toward s suburbs and outer suburbs. According to our experiment (Table 8) with the simulated rainfall erosion on man-dumped soil in Shenmu county of Shaanxi Province, it is found that the amount of sediment from the slopes of man- dumped soi l is much greater than that from uncovered natural slope land[9], although on the condition of the same rainfall indu ced erosion process (Figures 3 and 4). During the short period of time, under the stormy rain (A-Type) erosion, the a mount of sediment from man-dumped slope is 10.8-12.2 times that from uncovered slope land. Table 8 Post-storm sedimen t yield from different slopes after a storm event Water flow can gather rapidly on the urban roads composed of materi als such as bitumen, cement or bituminous concrete. The cities in the Loess Plateau receive all kinds of loose sandy soil, mud and sands, silt and dust from construction sites, industrial slag, mud on the wheels, uncovered slopes, mud dy paths and duststorms, which are washed into rivers by water flow from rainfall on city´s ground. In 1997-1998, we chose 30 spots at two blocks in Yan´an to monitor and gather water samples during storms. We found that there is muc h more sediment gathered by street flow on the city´s ground, and that at the beginning of street water flow the amou nt of deposits in water, most serious, can reach as high as 35.8 kg/m3. The amount of sediments will decrease swiftl y after a rainfall event one hour later (Figure 5). According to the analysis of data gathered, we can give the mode l of sediment transport by water flow on street roads in Yan´an, which is as follows: where Y is the amount of transp orted sediment, a1 and a2 are constants, t1 and t2 are water flow at beginning and finishing time respectively, Q1 an d Q2 are water flow on the street road during the earlier stage and later stage of rainfall process. 4.4 Periodicity and seasonal variation Rhythmic variations in the suburban erosion environmental conditions are caused by seasonal cl imatic variation. Weather conditions in different seasons cause regular variations in vegetation cover, landscape, er osion agents, erosion processes, and erosion intensities (Table 9). This variation reveals the internal relationship s between the environmental constituents as well as economic activities and the environmental conditions. Figure 5 Th e process of silt concentration changing in the street roads flow during rainfall Table 9 Example of seasonal variati on in urban environments of Yulin (YL) and Tongchuan (TC) The characteristic of the urban erosion environments is rel ated closely to urban expansion process and the development phase of national economy. Several phases of urbanizatio n have been experienced along with the macro-development of national economic construction. For instance, the city o

f Yan´an was primarily expanded in the late 1950s. Its second urbanization phase was from the late 1970s to mid 1980 s. The rapid urbanization started in the 1990s. The city of Xi´an had a large scale urbanization period from the lat e 1950s to early 1960s. From the late 1970s to mid 1980s Xi´an experienced another expansion period. Since the 1990s it has been a new expansion period, when the central area steadily developed, suburb area expanded, and more satellit e cities grew quickly. Each development turned more rural land to urban area, while the sizes of cities expanded. Man y areas of the region have become new urban soil erosion environments. 4.5 Quick variability Compared with the erosio n environments in rural areas, the suburban erosion environment manifests a rapid variation, especially, in an area o f a newly built city or where a city is at large scale expansion stage. Urban areas possess more human resources, mat erial, capital, and technical resources. As a center of economy, culture, politics, and communication, the urban are a has quicker economic growing speed than the rural area. Environments therefore experience more intensive impact by human activities. It brings more intensive stimulating factors to environments in a short period of time that change s the environmental constituents, or adds some new elements to the erosion system. This is true especially for the ne w developing area. For example, the limit of the city of Yulin in the Ordos Coal Mining area along the Great Wall exp anded from 8 km2 to 15 km2 in 10 years owing to the exploitation of coal, oil and natural gas. This variation has bro ught new combination of erosion factors of wind and multi-human agents replacing the wind predominant natural erosio n processes. However, the variation in urban and suburban erosion environment is not linear. It may undulate with th e variations in economic development. 5 Conclusions Urbanization in the Loess Plateau of China has accelerated the ex isting erosion and therefore worsened environmental problem since 1980. The urban areas have a quicker economic growi ng speed than the rural areas. These bring more intensive stimulating factors to environments in a short period of ti me that changes the environments, or adds some new elements to the erosion system. Therefore the environment experien ces more intensive impact by human activities. The possible impact of urbanization on environments must be taken int o consideration when designing or planning to exploit natural resources and to develop an area that may cause urbaniz ation. References

关键词： the Loess Plateau; urban erosion environment; impacts; characteristics

