

Soil Erosion Characteristics and Control Measures in China

*Yang Aimin*¹, *Wang Hao*¹, *Tang Kewang* and *Sun Ge*²

¹Department of Water Resources, China Institute of Water Resources and Hydropower Research, Beijing 100044, P.R. China

²Southern Global Change Program, North Carolina State University, Raleigh, NC 27606, USA

Abstract: Serious soil erosion problems exist in China due to long term anthropologic activities and its erosion-prone land forms and climate. A diverse soil erosion types throughout the country are caused by forces from water, wind, gravity, water and wind mixture, freezing and glaciers. According to erosion forces, the entire continent has been categorized to eight regions including Northwestern Loess Plateau, Northeastern Black Earth Hills, Northern Earthy Rockies, Southern Red Earth Hills, Southwest Earthy Rockies, Southwest Carst Rockies, Debris Flow-Prone Region, Northwest Arid and Semi-arid Deserts, and Freeze Dominated Erosion Region. Systematic soil erosion control in China started in the 1980s. Focuses have been on eight key regions encompassing seven large river basins such as the Yangtze River and the Yellow River. A comprehensive soil erosion control system has been developed that integrates land planning and management, biological based methods, engineering based methods, agricultural cropping technology and law enforcement. Soil erosion control has been based on small watershed and implemented on a county level under a comprehensive planning framework for mountain, water and cropland ecosystems.

1 Introduction

Modern accelerated soil erosion problems have been linked to irrational land exploration resulting from human activities. China with its huge population and land mass and variety of climates offer an ideal setting for studying how soil erosion and sedimentation are affected by natural and socioeconomic development. Lands in China has long been under intense population pressure since the late 1800s. At present, arable land per capita is merely less than 1/10 ha or 1/5 of the world average. Recent efforts of soil erosion control in China may also provide lessons and experience for other developing countries with similar problems. In general, in the past, such literatures are rarely available to the international communities due to language barriers. This paper reviews the characteristics of soil erosion cross a climatic and geographic gradients in China and summarizes control measures that are currently used in China. Our intention is to give an overview of the current soil erosion status and with hope to promote discussions within the international communities about the soil erosion issues in China.

2 Geography and climate

China is located in the east of Asian continent and the west shore of the Pacific Ocean (Fig. 1). The total land area of China is 9.6 million km² and the population is estimated as 1.28 billion by year 2000. The land is classified as Mountains, High Plateaus, Basins, Plains and Hills representing 33%, 26%, 19%, 12%, and 10% of the total area, respectively. The geomorphology is complex, with lower elevation in the east and higher elevation in the west. According to elevation distribution, three steps exist: the first step, Qingzang Plateau with an averaged elevation greater than 4,000 m; the second step with elevation ranging 1,000 m—2,000 m consisting Yungui Plateaus, the Loess Plateaus, Inner Mongolia Plateaus and the embedded Sichuan Basin, Tarim Basin, and Zhunger Basin; the third step includes areas with elevations lower than 1,000 m characterized as hills and plains that are located in the eastern parts of Danxinganling Mountain, Taihang Mountain, Wu Mountain, and Yungui Plateaus. Five climatic zones are found in China including frigid-temperate, temperate, warm temperate, subtropical and tropical zones that are dominated by eastern Asian monsoon climate. Annual precipitation distribution greatly affected by the distance to the pacific ocean, high in the southeast coastal regions (>1,500 mm) but low in the northwest inner lands (< 50 mm) (Fig. 2).

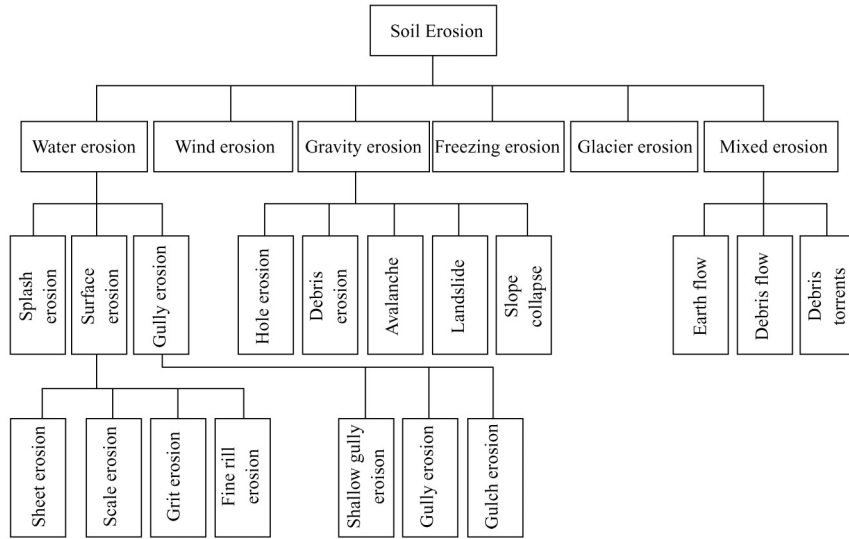


Fig. 1 China soil erosion classification systems

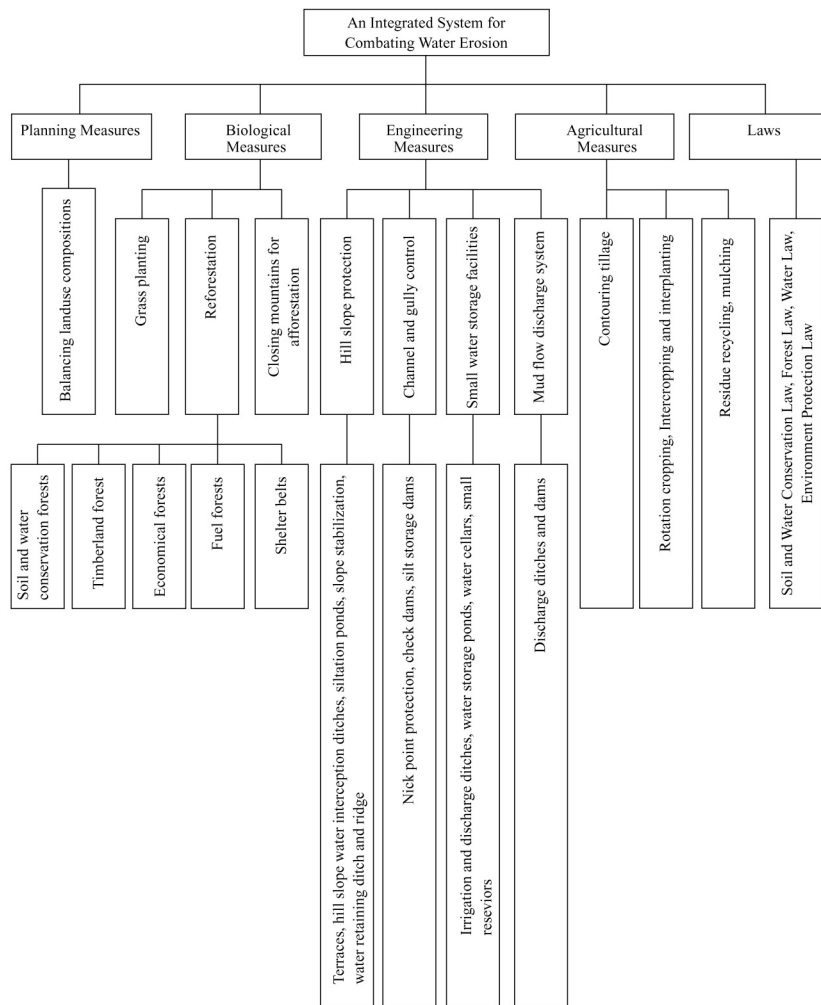


Fig. 2 A comprehensive system to control water erosion

3 Soils erosion types

According to soil erosion forces, erosion forms and potential control measures, the soil erosion types are classified as six large types: Water erosion, Wind erosion, Gravity erosion, Freezing erosion, and Glacier erosion (Fig. 3).

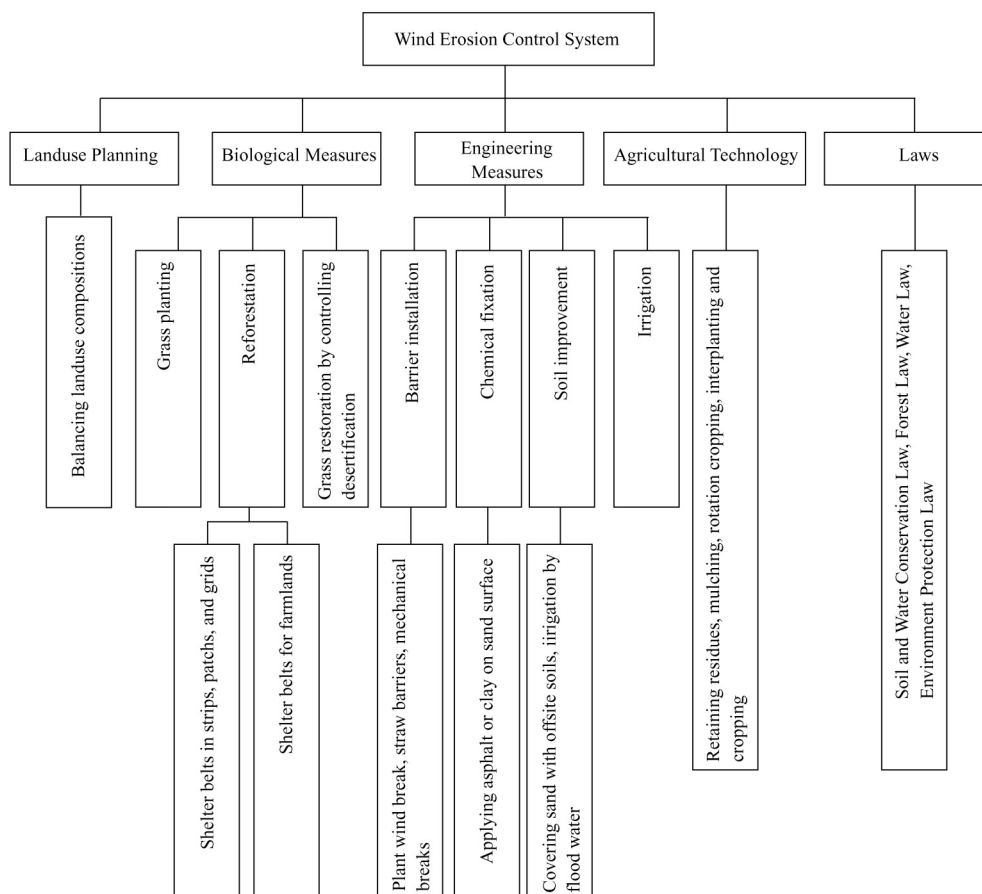


Fig. 3 A comprehensive system to control wind erosion

4 Distributions of Soil erosion by major river basins

According to remote sensing survey data published by the State government in 1990, about 3.67 million km² or 38.2% of the total land area was affected by some kind of soil erosion, equally distributed as water and wind erosion. It was estimated that the total annual soil loss was about 5 billion tons or 19.2% of the world's total soil loss, resulting decrease in 70,000 ha croplands. Over 1/3 of the land of the 7 major river basins was found under influence of soil erosion (Table 1). Total soil loss in the Yangtze River basin along was estimated as 2.4 billion tons with over half of the amount occurred in the upper tributaries. The Yellow River slated to be the world's most sediment-ridden river had an averaged sediment concentration of 37.6 kg/m³ with a maximum value reaching 590 kg/m³. The total soil loss from the Yellow River basin was estimated as 1.6 billion tons primarily occurred in the middle and upper reaches. Serious problems such as flooding and sedimentation resulting from soil erosion in those two major rivers had greatly affected the socio-economical development in the two regions as well as the entire nation as a whole. It is believed that the Chinese culture was mainly originated form those two basins.

Table 1 Soil erosion distribution by major river basins in China

Basin	Total land area (thousand km ²)	Area subject to soil erosion (thousand km ²)	Area under soil erosion (%)
Yangtze River	1,783.4	622.2	34.9
Yellow River	790.3	465.0	58.8
Haihe River	318.9	119.3	37.4
Huaihe River	266.8	59.4	22.3
Songhua and Liao Rivers	772.4	281.6	36.5
Pearl River	441.7	58.5	13.2
Taihu Lake	36.5	2.6	7.1
Subtotal	4,410.0	1,608.6	36.5
Other areas	5,190.0	2,061.4*	39.3
National Total	9,600.0	3,670.0	38.2

* including 1,160 thousand km² of desert.

5 Characteristics of soil erosion by regions

A diverse soil erosion types throughout the country have been found that are caused by various forces including water, wind, gravity, water and wind mixture, freezing and glaciers. According to erosion forces, the entire continent has been categorized as three first-class zones: water erosion dominated zone (I), wind erosion dominated zone (II), and freezing erosion dominated zone (III) (Fig. 3).

Water erosion-dominated zone (I)

The water erosion dominated zone, Zone I, is mainly distributed in the east of Daxinganling Mountain-Ying Moutain-Helan Mountain-Qingzang Plateaus. According to the geological, geomorphologic, and soil conditions, Zone I is further classified into five subclasses, Northwestern Loess Plateau (I₁), Northeastern Black Earthy Hills (I₂), Northern Earthy Rockies (I₃), Southern Red Earthy Hills (I₄), Southwest Earthy Rockies (I₅). Soil erosion characteristics and major causes for each region are described below.

As the most severe regions suffering soil erosion, the Northwestern Loess Plateau (I₁) is mainly distributed in the middle and upper reaches of the Yellow River basin and is uniquely found in northern China. The soils are often developed as thick as 100 m—200 m. The total land area is about 640, 000 km² with 340,000 km² and 110,000 km² subject to water and wind erosion respectively. The averaged soil erosion rate is estimated as high as 5,000—10,000 tons/(km² • year) and can go up to 20,000—30,000 tons/(km² • year) in some areas, and the annual sediment yield to the Yellow River was estimated as 1.6 billion tons. The main soil types in this region were characterized as surface and gully erosion. Surface erosion occurred on croplands with slopes 15°—25°, losing 75 ton • year/ha—150 ton • year/ha each year. Soil erosion has greatly degraded the soil as evidenced by reduction of crop production and increased frequency of draught. Gully erosion is common in this region with gullies covering 30%—40 % of the entire area. The gullies may develop 50 m—120 m deep and several meters to tens meters wide. The retreat of headwall, bank erosion, and downcut during the gully processes are often accompanied by avalanches, landslides, hole erosion, and debris slides causing large amount of sediment movement. The deposited sediment from summer storms has raised the Yellow River bed at a rate of 10 cm/year creating a 'hanging river' down streams. Hole erosion is unique to this region.

The Northeastern Black Earthy Hills (I₂) region is primarily located in the upper reaches of Songhua River, one of the 'food basket' in Northeastern China. Soil erosion in this region is mainly water driven

and less influence by wind. The hills have slopes around 2° — 4° mostly less than 7° . However, the slopes are often 800 m—1,500 m long thus have large surface collecting area and high flow rate. Due to the low erodibility and resistance to flow of black soils, the erosion rates have been documented as high as 3,000 ton/(km² • year)—6,000 ton/(km² • year) and soil depths have been reduced from 1.0 m—1.5 m in the 1950s to 0.2 m—0.3 m today. In many cases, surface erosion has been upgraded to gully erosion resulting in reduction of cropland area and productivity and increase in draught severity.

The Northern Earthy Rockies (I₃) region is primarily located in the lower reaches of the Yellow River and basins draining the Songhua River, the Hai River and the Hui River. The estimated area affected by soil erosion was estimated as 480,000 km² or 64% of the entire lands with averaged erosion rate as 1,000 ton/(km² • year)—2,000 ton/(km² • year). Shallow rocky soils dominate this region that are characterized as having steep slopes, high river bed gradients, and high percentage of rock exposure. In this region, floods and debris torrents are the common disasters directly resulted from soil erosion after intense summer storms often leaving large boulders and sediment at the watershed outlets and fertile flood plains and sometimes destroying residential prosperities.

As the most serious soil erosion region in extent and intensity, the Southern Red Earthy Hills region (I₄) is largely located in the middle and lower reaches of the Yangtze River and the Pearl River, and Fujian, Zhejiang, Taiwan and Hainan provinces. The total area subject to water erosion is estimated as 500,000 km² or a quarter of the entire land mass. In addition to the common erosion types of surface erosion and gully erosion, slope collapse is a unique form to this region. Surface erosion mainly occurred slope croplands and wastelands that are too bad to grow agricultural crops and even tree usually due to historical soil erosion. The erosion rates increase with slope degrees of the croplands, 15 ton/(ha • year)—30 ton/(ha • year) for 5° — 10° slopes and 45 ton/(ha • year)—75 ton/(ha • year) for 15° — 25° slopes. Generally, erosion on wastelands is light if a grass layer presents. However, this layer has often been eradicated for producing manure and fuels. Slope collapse often occurred in geologic regions dominated by weathered granite formation. The weathered loss materials often present 20 m—50 m deep in the forms mostly coarse quartz with large particle sizes. Soil erosion has greatly reduced soil productivity and sediment has caused serious impacts on the normal functions of reservoirs, water transportation, irrigation and lakes. As long as the surface runoff accumulates and concentrates on hillslopes without vegetation, a slope collapse will be initiated at the nickpoint or the starting point of a future collapse and develops uphill hounds meters with a 10 m—20 m down cut. Erosion rate for this kind area is high up to 4,000 ton/(km² • year)—8,000 ton/(km² • year).

The Southwest Earthy Rockies (I₅) region covers part of the upper reaches of the Yangtze River and Pearl River, Sichuan, Yunnan and Guizhong Provinces and Guangxi Autonomous Region, and western Gansu and Shaanxi Provinces. The total soil erosion area is about 340,000 km² or 1/3 of the land area. According to erosion features and the potential impacts, this region is further classified as two sub-regions: Limestone Mountain Zone and Debris Flow Prone Zone. The Limestone Mountains Zone is located primarily in Guizhou Province and Guangxi Autonomous Region in southern China neighboring Vietnam, Laos, and Burma. The topography of this sub-region is characterized as having high elevation, deep slopes, deep valleys with high river bed gradients and shallow soils (10 cm—30 cm). Soil erosion rate is about 2,000 ton/(km² • year)—5,000 ton/(km² • year). In this Carst dominated geologic region, runoff often changes forms from surface flow to subsurface flow. Slope lands that have slopes about 20° — 30° are the major and the only land base for agricultural crop production. Impacts of soil erosion are disastrous often causing permanent loss of soil productivity as evidenced by the many bared mountains in this region today. The importance of soil resources to the sustainability of the local community has been well recognized. The second sub-region of I₅, Debris Flow Prone zone is located in the lower reaches of Jinshajiang River and mountainous regions of southern Shaanxi and western Sichuan. Erosion rates are extremely high ranging from 50,000 ton/(km² • year)—100,000 ton/(km² • year). This region is characterized as high absolute elevation (1,500 m—3,000 m) and high relative elevation difference (200 m—300 m), steep hillslopes ($> 30^{\circ}$), shallow soils with exposed rocks. This region has high occurrence frequency of debris mud flow caused by intense storms and the unique geologic environment. For example, along a short distance of 752 km in the lower reach(reaches) of the Jinshajiang River, 258 sub-watersheds or 70% of the entire basin were found to have been impacted by debris flow.

Wind erosion-dominated zone (II)

Desertification problems in northern China has drawn much attention from the public after the dust storms struck 20 times in recent years and 9 times in Beijing in the spring of 2000 alone. Zone II is primarily located in the semi-arid and arid regions in northwestern China. The total area was estimated as 1.88 million km² with 1.16 million km² classified as deserts that may not be controllable. Major deserts with large extent include Taklamagan Desert within the Tarim Basin, Guerbantongte Desert within the Zhunger Basin, both located in the Xinjian Uygur Autonomous Region, and Badanjilin Desert located in the Inner Mongolia Autonomous Region. A series of national desertification combating efforts (engineering and shelter-belt construction) in the past half a century has resulted positive effects. However, due to the population pressure and limited natural resources (fuel, forage, and mature) and lacking environmental awareness in the region, the restoration could not keep up with destruction in general and the desertification areas has in fact expanded. According data from the remote sensing monitoring, the degraded grassland in the Inner Mongolia along was doubles or a net increase of 174,000 km² in area.

Freezing erosion dominated zone (III)

Zone III covers western Qingzang Plateau, Tianshang Mountain in Xijian, and the Helongjiang River basin, Daxinganliang Mountain and Xiaoxinganling Mountain in the tundra (frigid zone) of northeastern China. Because the human population is low in this zone, erosion is minor and generally occurred at the geologic erosion level. Soil erosion control policies focus on monitoring and protection.

6 Comprehensive soil erosion control systems and measures

Since the 1980s, large-scale watershed management and ecological reconstruction programs have been implemented in key areas throughout China that had serious water erosion problems. Past efforts have focused on eight key regions and seven large river basins including the Yangtze River and Yellow River that require taking immediate soil erosion control measures and ecologic restoration. A comprehensive soil erosion control system as a model suited to the socioeconomic conditions of China has been developed. Soil erosion control should be conducted using following principles:

- (1) Systematic land planning should consider the inter-relations between mountains, water, crop land and roads. Planning should be done at a county level.
- (2) Erosion control measures should be implemented at a small watershed scale under the framework of a large basin.
- (3) Erosion control measures should integrate the engineering, biological, and soil and water conservation based tillage technologies.
- (4) Erosion control measures should balance the ecological, economic and social benefits.

Wind erosion research and control practices began in the early 1950s in China. A comprehensive erosion control system has been developed.

7 Conclusions

A combination of climate and topographic environmental factors resulted in the diverse soil erosion distributions in China. Soil erosion rates are high in most China's mountainous regions due to land use pressure. In northern China, water erosion in the dry Loess Plateau region with thick soils and desertification due to over-grazing of grasslands are the main problems. In contrast, soils in the humid Southern China are shallower and land pressure has been even acute, thus soil erosion may result permanent loss of land productivity. Although a comprehensive system to control soil erosion and desertification has been in place, success of implementation has been limited due to the high demands on land resources from a large population in China.

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