Research Article

Investigation of Soil Erosion in Pothohar Plateau of Pakistan

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Abstract | The research aims to investigate soil erosion in Pakistan in order to provide a scientific basis for the prevention and control of soil erosion in Pakistan and for the understanding of the ecological environment status in Pan-Third Pole. The Pothohar Plateau was selected as the representative area of soil erosion in the country. Along the route of Muree-Islamabad-Rawalpindi-Gujar Khan-Chakwal, 15 investigation units (12 small watersheds and 3 rectangular areas) were selected to investigate the types and characteristics of soil erosion, land use types and soil and water conservation measures, from April 16 to 20, 2019. Map interpreted in the early stage was manually recorded and Ovi interactive map APP was used for location photography to record the land use situation of each map spot in the survey unit. The land use situation was revised based on ArcGIS in the later stage. The overall soil erosion of woodland and grassland was relatively light with sheet erosion as the main type. Soil erosion mainly occurred in construction land. Gully erosion was caused by rainfall and runoff on excavated slopes, dump slopes, roadside slopes and brick factories. Due to overgrazing, gravity erosion and gully erosion also occurred in some natural hillsides. The range of soil erosion of the 15 investigation units was about 5.14~133.89 t ha^{-1} $year^{-1}$. The soil erosion in Pothohar Plateau mainly occurred in construction land. The soil erosion caused by development and construction projects should be supervised and controlled, meanwhile, matching soil erosion prevention measures should be developed through research. Especially Murree region in the north requires rational planning and approval of a large number of construction projects to prevent the intensification of soil erosion and the deterioration of water quality and ecological environment. The research and control on headwater erosion in the gully region should be strengthened to protect farmland and ensure food security. It is recommended that collection of basic data on soil erosion, and study of the mechanism and process of soil erosion at different scales should be strengthened in order to protect the land resources in Pakistan.

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Introduction

Pan-roof region of the world covers an area of 2.00×107 km^2 and has a population of more than $3.00×10^8$. At present, it faces such environmental problems as sharp temperature rise (Liu *et al.*, 2017), glacier melting and intensified desertification (Liu *et al.*,2017). Pan-roof region is highly coincident with the "the belt and road initiative" economic belt proposed by China. Understanding, studying and solving the

resource and environment problems in the region are important links in the implementation process of the initiative. Pakistan is an important member of pan South Asian countries. The investigation of soil erosion status and control efforts in this region would be of great significance to conserve pan-roof of the world.

In recent years, Pakistan's population has increased dramatically. The UN Population Planning and Forecasting Committee predict that by 2025, the population will reach 2.60×10^8 (Xie, 2004). Although Pakistan is a large agricultural country in South Asia, with agriculture contributing 25% of GDP (Yin, 2014), Pakistan's arable land is only 0.2×10^6 ha, and its population and arable land are concentrated on both sides of the Indus River and its tributaries (Yang, 1993). Moreover, 76% of its land is affected by different degrees of soil erosion, which has posed a great threat to animal husbandry and ecological security in the country (Zhang, 1997). In terms of human factors, activities such as deforestation, land reclamation, overgrazing and unreasonable farming after population increase (Zhang, 1997), aggravate soil erosion. From the aspect of natural factors, the Indus River Basin is prone to water erosion due to large rainfall and loose soil (Muhammad *et al*., 2012). Soil erosion not only leads to the continuous loss of nutrients from the surface of the soil in agricultural land and desertification of the land, but also pollutes the downstream water (Muhammad *et al*., 2012). Therefore, the research aims to investigate soil erosion in Pothohar in order to provide a scientific basis for the prevention and control of soil erosion in Pakistan and for the understanding of the ecological environment status in Pan-Third Pole.

Survey area overview

Pakistan (23 45'-36 56' N, 60 53'-71 03' E) borders China in the northwest, India in the east, Iran and Afghanistan in the west. Pakistan has a land area of about 8.81×10^5 km (including Azad Jammu Kashmir region) and a length of about 160 ha from north to south. It has many geomorphic types such as plains, hills, plateaus and mountains. Most parts of Pakistan belong to tropical arid and semi-arid climate and are located on the western edge of tropical monsoon region. The annual rainfall is 50 ~ 1,000 mm, with uneven distribution of rainfall. The annual rainfall in the northern region can reach 2,000 mm (Peng and Lei, 2017). Pakistan's topography is changeable and can be divided into northern high mountains, Pothohar plateau, Punjab plain, Baluchistan plateau and Sindh plain, etc. There are also many types of eroded land forms. Among them, the high mountain area in the north is common one; so far it is also the origin of major rivers such as Indus River, Jhelum River and Chenab River. The southern part of the high mountain area is the Pothohar Plateau (32 13′-34 22′ N, 71 18′-73 57′E), with an area of about 22 ha. The central part of the plateau consists of plain and ravine regions, with a gradient ranging from 8% to 40%. It is an important food production place in Pakistan (Amir *et al*., 2019), and is also a political and cultural center (Islamabad is located in the northern part of the Pothohar Plateau). The annual distribution of rainfall on the Pothohar Plateau is uneven. About 70% of the rainfall is distributed from July to September (Amir *et al*., 2019). Therefore, the rainfall is more erosive and the soil erosion is serious. It is the region with the most serious water erosion in Pakistan. The total erosion amount is about 4.24×10^8 t year^{-1}, of which the average annual erosion amount in the western (Attock) and eastern (Jhelum) regions is about 8.00×10^7 t year^{-1}, while that in the northern region (Rawalpindi) is as high as 1.60×10^8 t year^{-1} (Ullah *et al*., 2018; Muhammad *et al*., 2012). In the northern region of the Pothohar Plateau, even in forest areas with high coverage, erosion is more serious in some areas. In addition, the Tarbela Reservoir in this region is the main source of water for Islamabad's city and nearby agriculture. The Indus River pours 50,000 t of sediment into the reservoir every day, which greatly shortens the service life and storage capacity of the reservoir (Muhammad *et al*., 2012).

Survey content and method

Layout of sample points and investigation route: The population is densely distributed near Islamabad, the surface environment is seriously disturbed by human beings, and the land use changes occur rapidly. Therefore, based on the annual rainfall change (500~1400 mm, Fick and Hijmans, 2017), the diversity of land use and topography, a sample line is laid in the northeast-southwest direction of Islamabad, and 15 survey units (12 small watersheds and 3 rectangular areas) with an area of 0.074~0.214 ha were selected at intervals of about 0.1 ha for field survey (Figure 1). The basic information of the survey units is shown in Table 1.

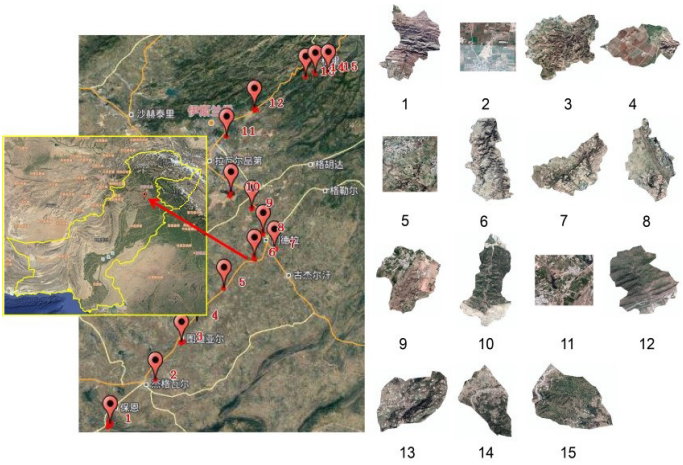


Figure 1: *Soil Erosion Survey Route and Distribution Location of Survey Units inPothohar Plateau, Pakistan.*

Investigation methods and contents

According to the classification standard of land use in the soil and water conservation survey of the first China water conservancy survey (Guo, 2014), the land use and water conservation measures map interpreted in the early stage was manually recorded and Ovi interactive map APP was used for location photography to record the land use situation of each map spot in the survey unit. The land use situation was revised based on ArcGIS in the later stage. The interpretation result is shown in (Figure 1). At the same time, the geographic location, soil erosion characteristics, vegetation types and coverage, and the utilization status of agricultural land in different areas were investigated and recorded, and a total of 1,026 map spots were investigated in 15 investigation units (Figure 1). Then, the soil erosion rate t ha^{-1} $year^{-1}$ of each spot in each unit is calculated by using the China Soil Loss Equation (CSLE), so as to analyze the soil erosion degree and spatial distribution characteristics of each sampling unit. China Soil Erosion Model (CSLE) is an improved model based on the U.S. Universal Soil Loss Equation (USLE) and according to China's soil erosion characteristics, experimental observation data and treatment techniques. CSLE changed USLE's LS algorithm to one applicable to steep slopes, and changed vegetation cover and management factor (C) and soil and water conservation measure factor (P) to three factors of soil and water conservation biological measure (B), engineering measure (E) and tillage measure (T) (Liu *et al.*, 2013; Fu and Zhou, 2015; Li *et al.*, 2012). CSLE has been successfully applied in Xinjiang (Guo, 2014) (bordering Pakistan), Shaanxi Province (Ma *et al.*, 2018) and other parts of pan-roof of the world such as different terrains, climate zones (Metcalf *et al.*, 2012; Li *et al.*, 2018). Therefore, the model is used in the calculation of soil erosion modulus of the sampling units in this survey.

CSLE factors and loss rate calculation method

The calculation method of CSLE factors in China's first hydraulic census (Guo, 2014) is used to calculate regional soil erodibility factor (R) and soil edibility factor (R). Using SRTM data with 1 arc second resolution and LS_Tool calculation tool to calculate the slope length factor (LS) Based on NDVI and PVI data and field survey data, calculate soil and water conservation measure factors (B, E, T). Finally, the soil erosion rate (A) was calculated by CSLE.

Soil erosion characteristics and soil erosion control measures

Soil erosion characteristics of land use types: Soil erosion characteristics of forest land: Forest land is mainly distributed into Murree area in northeastern Pothohar (survey unit 13-15). Arbor forest land (mainly *Pinus massoniana*) can account for 28.87% ~ 69.90% of the total area of the survey unit, with an average canopy density of over 50% and an average soil erosion rate of 24.817~72.344 t ha^{-1} $year^{-1}$ (Table 2). Under natural conditions, the degree of soil erosion is relatively light, only some forest land has flaky erosion (Figure 2a), and some hillside slopes have gravity erosion (Figure 2b); however, in the production and construction project area, the exposed slope is seriously eroded (Figure 2c) and even produces large cut-off grooves (Figure 2d cut-off grooves are about 20 m long, 1-5 m wide and 1-3 m deep). The main cause of sheet erosion in forest land is that, the grass in pine forest land is sparse. After rainfall, water is collected, overflow occurs, and the erosion resistance of the surface is relatively weak in areas without grass coverage. Therefore, large scale erosion occurs, even below. There are two possible reasons for the thinning of grass: the annual rainfall here is 1,200~1,300 mm (Table 1), so *Pinus massoniana* grows luxuriantly and greatly (individual trees are as high as more than 40 m). *Pinus massoniana* forest competes with undergrowth herbs for nutrients and water, resulting in thinning of grass in the forest. Studies on *Pinus massoniana* have confirmed that it secretes allelochemicals and will affect the growth of other plants nearby (Duan *et al.*, 2016). In the production and construction project area, due to the destruction of vegetation, the soil loses its protective layer. Under the direct impact and erosion of rainfall and runoff, the erosion is intense, resulting in rill erosion and gully erosion. Soil fine particulate

Table 1: *Basic information of soil erosion survey unit in Pothohar Plateau.*

Investigation unit number	Date of investigation	Average annual rainfall (mm)	Altitude (m)	Geomorphological features	Major land use
1	20190420	520	600~700	Mountain area, multi-sandstone	Forest land, cultivated land
2	20190420	500	517~526	Plateau area, flat terrain	Cultivated land and construction land
3	20190420	600	524~554	There are wide and shallow ravines in the plateau area and survey unit, accounting for about 40% of the area.	Cultivated land and grassland
4	20190416	640	498~525	There are ravines in the eastern part of the survey unit in the plateau area, accounting for about 15% of the area.	arable land
5	20190420	720	508~528	Plateau region	Cultivated land and construction land
6	20190419	800	517~575	There are wide and shallow ravines in the plateau area and survey unit, accounting for about 45% of the area.	Cultivated land and grassland
7	20190419	820	502~535	There are wide and shallow ravines in the plateau area and survey unit, accounting for about 20% of the area.	Cultivated land and grassland
8	20190419	800	487~524	There are wide and shallow ravines in the plateau area and survey unit, accounting for about 5% of the area.	Cultivated land and grassland
9	20190419	900	543~580	How wide and shallow ravines are there in the plateau area and survey unit, accounting for 35% of the total area	Cultivated land and construction land
10	20190418	900	438~532	hilly area	Woodland, grassland
11	20190417	1000	499~520	stream terrace	Cultivated land and grassland
12	20190417	1100	592~816	Mountain area	Woodland, grassland
13	20190418	1200	1 111~1 385	Mountain area	Cultivated land and forest land
14	20190418	1200	1 161~1 755	Mountain area	Woodland, grassland, cultivated land
15	20190418	1300	1 425~1 928	Mountain area	Woodland, grassland, cultivated land

Table 2: *Average soil erosion rate of each survey unit.*

Investigation unit number	Survey unit area (ha)	Average soil erosion rate of major land uses (t ha^{-1} year^{-1})				Average erosion rate (t ha^{-1} year^{-1})
		Arable land	Woodland	Grassland	Construction land	
1	0.106	49.654	4.611	2.623	7.942	15.08
2	0.100	54.045	.000	1.879	2.492	41.91
3	0.202	70.374	30.647	30.647	1.921	47.74
4	0.074	86.401	2.803	2.276	1.709	76.02
5	0.164	119.930	2.448	0.993	3.230	85.30
6	0.203	228.328	4.756	4.109	2.729	116.44
7	0.134	147.647	2.732	2.834	14.665	111.71
8	0.164	86.252	1.951	1.205	3.514	47.61
9	0.143	180.354	4.552	4.227	6.373	57.75
10	0.204	0.000	9.298	4.564	50.184	18.62
11	0.108	133.951	1.115	1.554	4.955	55.54
12	0.214	0.000	4.921	5.225	12.842	5.14
13	0.082	190.888	24.817	5.700	53.296	133.89
14	0.152	336.953	60.724	20.513	171.176	110.70
15	0.106	86.394	72.344	71.681	71.645	71.64

matter moves with runoff, and underground gravel gradually emerges, causing damage to the natural landscape.

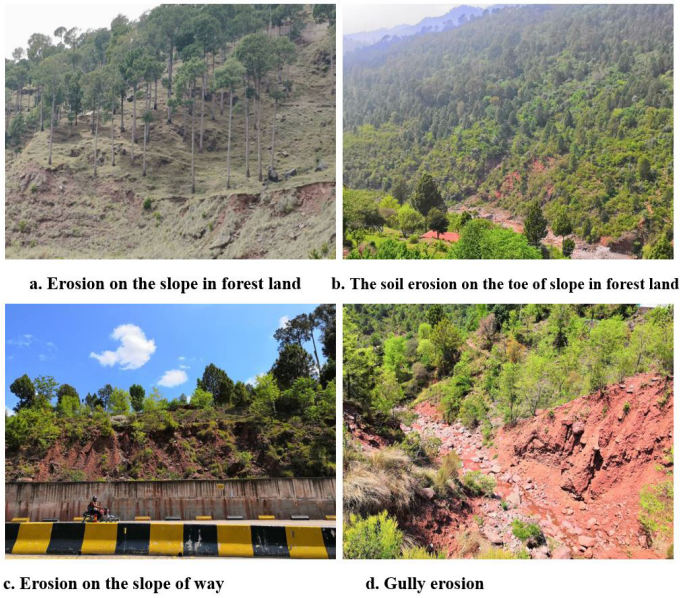


Figure 2: *a: Wide shallow erosion gully channel; b: Rill and gully erosion; c: Gravity erosion; d: Gravity and gully erosion.*

There are two main reasons for gravity erosion at the foot of the slope: Northern Pakistan is the Himalayan mountain rising region (Li and Xu, 1983), so the slope is long and steep, the stress is concentrated at the foot of the slope, which is prone to collapse; The rainfall in this area is large, and the slope toe is an area where runoff collects. The water is sufficient, and the cohesive force between soil layers is reduced due to the action of water, so it's easy to collapse.

Characteristics of grassland soil erosion: Within the investigation scope, the grassland is mainly distributed in Gujar-khan area of Rawalpindi (Unit 3-9). Its area can account for 16.70%~37.75% of the total area of the investigation unit, and the average soil erosion rate is between 0.99 ~ 30.65 t ha^{-1} $year^{-1}$ (Table 2). The average annual rainfall in this region is 498~580 mm, which belongs to semi-humid climate. Under natural conditions, grass cover grows better and the erosion degree is lighter. Sheet erosion is distributed on the slope surface. The reason is that under the action of rainfall and runoff, fine soil particles in areas without vegetation cover are continuously transported, gravel is gradually exposed and severe erosion occurs. In addition, erosion gullies also occur on the surface under the action of long-term erosion (Figure 3a). Under the influence of human activities, the grassland has relatively serious soil erosion. As there is no vegetation measure to protect the soil road slope, the soil is loose and the rainfall is easy to collect, resulting in a large amount of rill erosion and gully cutting in some areas (Figure 3b). Natural hillsides with high grass coverage were cut due to road repair, and areas without grass protection lost the consolidation effect of vegetation on soil, resulting in constant gravity erosion such as runoff and scattering, in sharp contrast to areas with grass coverage (Figure 3c). Grazing activities can cause serious damage to grass. Herbivores eat plant stems and leaves, affecting plant growth, reducing surface coverage; trampling makes surface soil compact, and its water storage performance decreases. Under rainfall conditions, runoff is usual, resulting in gravity erosion and gully erosion (Figure 3d).

Figure 3: *Soil Erosion of Grasslands (Sparse Trees) in Gujar Khan Region (Taken by Jiao Juying from 2019-04-18 to 2019-04-19).*

Soil erosion characteristics of construction land: Pakistan's population and economy are growing rapidly (Yin, 2014), and development and construction will inevitably take place. During this survey, 80% of the survey units have construction projects, with an average soil erosion rate of 1.71~171.18 t ha^{-1} $year^{-1}$ (Table 2). During the construction of the project, the surface vegetation is destroyed and the soil is seriously disturbed, which easily lead to soil erosion. For example, on the east side of the 10th survey unit (Figure 1), there was about 5 km^2 of construction land, and the primary vegetation on the surface has been completely destroyed. The soil-discharging slope (Figure 1) has sparse vegetation and loose soil, resulting in serious rill and gully erosion. In addition, the soil-discharging slope is distributed in multiple stages, and each stage platform forms a catchment area for the next stage. Therefore, the lower the soil-

discharging slope, the more rill and gully formed, and the greater the depth and width. Although the coverage of surface vegetation formed by abandoned soil along roadsides is relatively high, many large ditches are formed (Figure 4a, the ditches are about 30 m long, 0.5 ~ 2 m deep and 0.5 ~ 5 m wide), mainly due to the long surface slope formed after the abandoned soil is spread out, resulting in large runoff, and the soft soil, the grass cover layer cannot fully absorb water and disperse runoff, resulting in large ditches, causing serious damage to local land resources. In the 5th investigation unit (Figure 1), there are small brick factories. During the brick making process, a large amount of soil was taken, resulting in bare surface, reduced erosion resistance and gully erosion (Figure 1). As the surface of the earth is continuously compacted by vehicles, the soil infiltration capacity of the earth taking platform is greatly reduced, and the earth taking platform itself forms a large catchment area. Under rainfall conditions, the side slope of the earth taking platform is easy to generate fine ditches and cut ditches (Figure 4b). In addition to the above types of construction, there are also soil erosion to varying degrees in the construction of leveling ground and high-pressure towers, causing damage to local water and soil resources.

Soil erosion rate of survey unit

The average value of soil erosion rate of 15 investigation units calculated by CSLE is between 5.14 ~ 1 33.89 t ha^{-1} $year^{-1}$ (Table 2). Muhammad *et al.* (2012) measured soil erosion rates in two small watersheds in the Chakwal region (located in the southern Pothohar plateau) range from 479 to 123.1 t ha^{-1} $year^{-1}$. Ellis *et al.* (1994) measured soil erosion rates in high-altitude deforested land and low-altitude overgrazing land in Murree area (located in the northern part of Pothohar plateau) are about 15,00 t ha^{-1} $year^{-1}$ and 50 ~ 7,50 t ha^{-1} $year^{-1}$. These two sets of data represent the erosion rates in areas with large human interference. At present, the only measured value of soil erosion in Pothohar Plateau is about 47.9~1500 t/ha, which shows that the calculation result of CSLE model is basically in this range. Therefore, the calculation results of CSLE model have better credibility and can be tried to popularize the model in a wider range. The soil erosion rate of land use is the average value obtained by statistical calculation of the soil erosion rate of all patches (cell) of each land use within the survey unit. The average soil erosion rate is the average value obtained by statistical calculation of soil erosion rates of cell within each investigation unit.

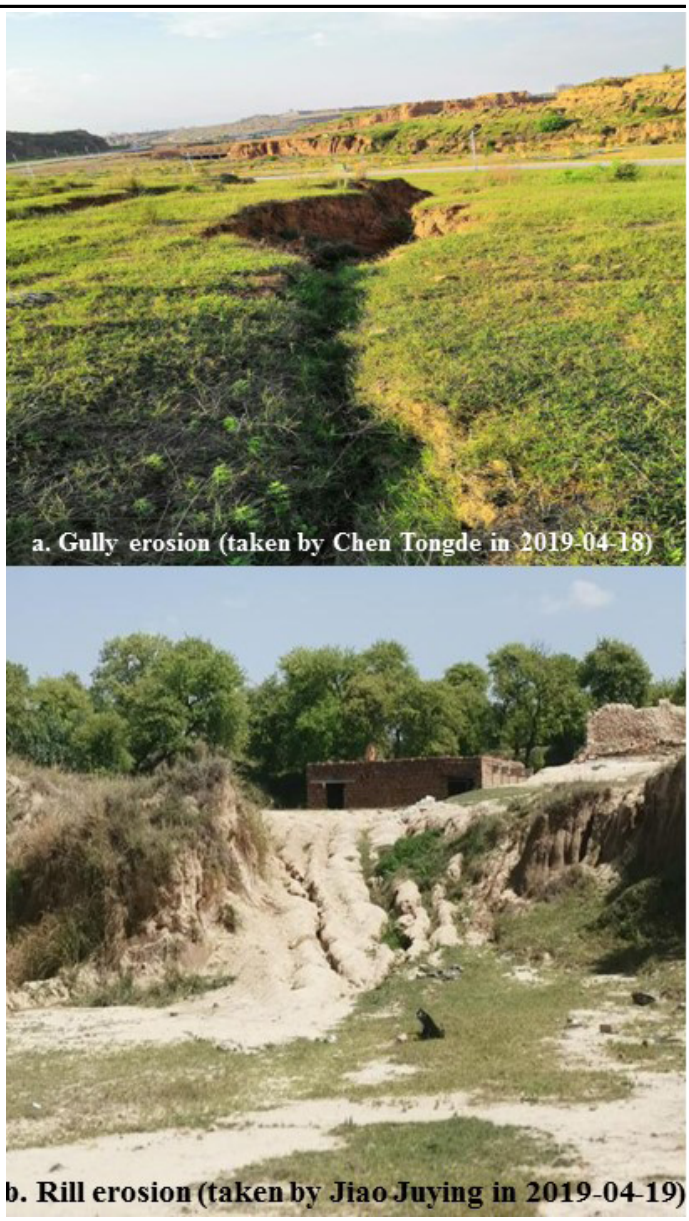


Figure 4: *Erosion Gully of Construction Land in Punjab and Northern Mindra in Islamabad Capital District.*

Soil erosion control measures

During this investigation, it was found that there are relatively few types of soil and water conservation measures in Pothohar Plateau, mainly including horizontal terrace stone masonry revetment for drainage ditches, small stone grain houses, farmland ridges, grass cover revetment, etc. (Figure 5). Horizontal terrace, masonry revetment (Figure 5a) and small dams (Figure 5b) are mainly applied to the Murree mountain area in the northern part of the Pothohar plateau, where the mountain is steep. For the sake of production safety, the local people usually excavate horizontal terraces according to the mountain. Masonry revetment is generally used on the adjacent slopes of horizontal terraces, and drainage ditches are used to guide and drain the horizontal terraces and the upper catchment water to prevent

the occurrence of traceable erosion and damage to the horizontal terraces. Small catchment is usually built at the outlet of the catchment area, and each dam is provided with a drainage pipe to achieve the effect of water removal and sand retention. Horizontal terraces are common in Murree mountain area. Most houses are built on horizontal terraces. At the same time, farmland is reclaimed around houses (similar to the Shikan terraces in China). Due to slope cutting and grading, the stability of horizontal terraces is very good. Besides, masonry or masonry revetment ensures that horizontal terraces are not washed away by runoff. These horizontal terraces have both production and ecological functions and are a kind of good soil and water conservation engineering measures in mountain areas. Within the scope of investigation, it is found that the gradient of farmland is very small, and farmland is seldom eroded, and most farmland is built with trapezoidal ridges of good quality (Figure 5c). This kind of ridge is quite different from that of China. The ridges in China are generally in the shape of a long strip, while the ridge in the Pothohar Plateau is a trapezoidal ridge with the inner side of the farmland being about 0.3 m long, the outer side being about 1.5 m long and the top being about 0.5 m wide. As the outer length of the trapezoidal ridge is much longer than the inner side, the stability of the trapezoidal ridge is better than that of the strip ridge. The ridge prevents the occurrence of soil erosion in the farmland and has a good protective effect on the environment inside the farmland. Although only simple grass cover is used for slope protection of railway slope (Figure 5d), the effect is good and no obvious soil erosion occurs, which may be due to the flat terrain, short slope and small catchments in the railway area is built, making it difficult to generate runoff during rainfall. In addition, about 0.2 m of gravel (ballast) was paved on train tracks. Rainfall enters the large pores between the gravel and do not converge to the railway slope.

Analysis of the main influencing factors of soil erosion

The influencing factors of soil erosion in Pothohar Plateau are divided into natural and human factors. The plateau itself has good natural conditions, with an average rainfall of 500~1900 mm from south to north, i.e. the whole plateau is semi-humid and humid, so the natural vegetation coverage is better and the degree of soil erosion is lighter in regions with less human influence. However, at the same time, the large rainfall in the northern mountainous area, steep slope, concentrated rainfall in the southern region and large rainfall erosivity, all provide potential favorable conditions for the occurrence of soil erosion. When human activities destroy vegetation, severe soil erosion will occur. Therefore, human activities are the dominant factors affecting soil erosion in Pothohar Plateau. Pakistan has a large proportion of agricultural population and is relatively poor as a whole. It is highly dependent on natural resources. Deforestation, overgrazing and farmland reclamation have caused severe erosion (Zhang, 1997). More importantly, because of poverty and low education popularization rate (Xie, 2004), there is not enough policy or awareness to prevent soil erosion and protect water and soil resources in the process of production and construction activities, both at the government level and among the general public. For example, a large number of scattered and disorderly residential areas in the northern mountainous areas are destroyed by deforestation and construction and exposed to erosion. The central and southern regions are generally flat, with an altitude range of about 500~600 m, but with a large population distribution (survey unit 3-9), and various types of projects under construction produce serious soil erosion (as shown in Figures 4 and 5, including loose deposits, newly excavated surface and intensity disturbed ground, etc.).

Figure 5: *Types of Soil and Water Conservation Measures in Pothohar Plateau.*

Conclusions and Recommendations

Soil erosion mainly occurs in the construction land, including gully erosion caused by rainfall and runoff on excavated slopes, soil drainage slopes, and soil

roadside slopes and brick factory platforms. Due to gentle slope and high ridge size, the characteristics of soil erosion are not obvious. Due to overgrazing, gravity erosion and gully erosion occur in some natural hillsides. Therefore, water and soil conservation planning, supervision and management of production and construction projects are very important. The average soil erosion modulus of 15 survey units was between 5.14~133.89 t ha^{-1} $year^{-1}$ which indicated that the calculated result has certain credibility and can be tried to popularize the model in a wider range. The accuracy evaluation of CSLE model calculation results should be based on comparative evaluation of sediment data obtained from runoff monitoring plots, therefore a plot should be built in Pakistan to further evaluate the applicability of CSLE model in the country.

Strengthen basic research on soil erosion

Soil erosion not only degrades farmland and grassland, but also increases the sediment content of rivers (the annual sediment transport of Indus River can reach 4.35×108 t, Muhammad *et al*., 2012), affecting the ecological safety of the downstream. The research on regional soil erosion in Pakistan mostly uses the models developed by other countries such as USLE, and there are few calibrations when using them, which makes it difficult to ensure the accuracy of the results. In the future, a suitable soil erosion model should be developed based on the characteristics of soil erosion in Pakistan.

Importance of the prevention and control of traceable erosion in gully regions of plateau

Pothohar Plateau is flat generally, with a large amount of cultivated land distributed. The land use results of the survey unit show that the proportion of cultivated land cans reach up to 86.89%. At the same time, as a result of long-term hydraulic erosion, a large number of wide and shallow gullies are distributed on the plateau, and the gully area is still expanding. Take the gully area near the research farm (URF) of PMAS-Arid Agricultural University in Cahkwal region as an example (Figure 6). The area of No.1 and No.2 gully expanded from 67,100 m and 26,046 m in 2001 (Figure 6a) to 154,838 m and 44,256 m in 2018 (Figure 6b) (the area is drawn in Google earth to obtain the area). The average expansion rate can reach 5,161.06 m/a and 1,071.18 m/a, respectively. This geomorphic type may be similar to the early state of the gully region of the Loess Plateau in China. Its main geomorphic units include tableland and ravines. At present, a large number of researches on traceable erosion and gully protection have been carried out in china. If the gully head in the gully region of Pakistan is not treated, the landform type may evolve towards the landform in the gully region of the Loess Plateau (China), and a large amount of cultivated land will be destroyed.

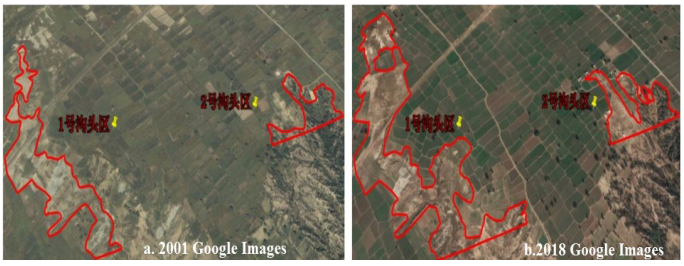


Figure 6: *Gully head changes near research farm (URF) of PMAS Arid Agricultural University (near unit 4).*

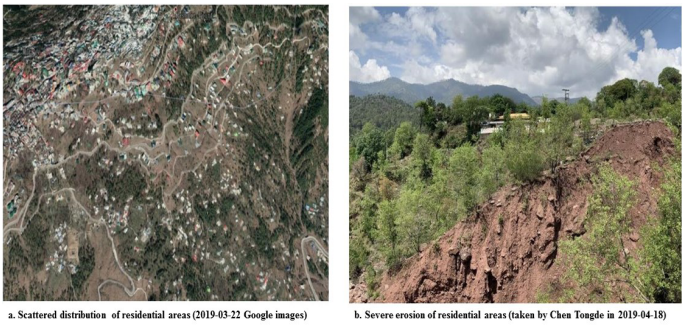
Implementation of water and soil conservation planning, supervision and management of production and construction projects

Pakistan is a country with a rapidly developing economy and population. There is still much space for improvement in infrastructure construction (Yin, 2014). The water conservation area should be planned as an ecological protection area and no man-made destruction should be allowed. However, during the investigation, it is found that a large number of residential areas are scattered randomly in the forests (Figure 7a), and severe soil erosion has occurred in some development areas (Figure 7b). Hence, a large number of development projects need unified planning and approval.

How to effectively supervise and control all kinds of man-made erosion?

At present, Pakistan does not supervise the soil erosion of production and construction projects, and the prevention and control measures are weak. It is urgent to carry out targeted supervision and arrange soil erosion control measures for various construction projects. We can learn from China's experience in this regard. In terms of supervision and management, China has entered the "3S" era of supervision and inspection from previous documents, reports, spot checks and other methods, featuring high efficiency, speed, and accuracy (Wang *et al*., 2017); In terms of soil erosion prevention and control measures, for production and construction projects, China has taken some serious steps, such as straw curtain (Liu *et al*., 2014), non-woven fabric, sunshade net cover (Luo

et al., 2013) and "Salix checkerboard+Shatawang" (Chen *et al*., 2017).



a. Scattered distribution of residential areas (2019-03-22 Google images) b. Severe erosion of residential areas (taken by Chen Tongde in 2019-04-18)

Figure 7: *Distribution of Residents in Murree Region.*

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Novelty Statement

GIS and Remote sensing based surveys of erosion status of Pakistan are limited. This study will fill the gap by providing comprehensive information based on latest tools.

Author's Contribution

Chen Tongde: Photographed during survey and interpreted land use images.
Fakher Abbas: Conducted the survey and applied statistic to data.
Jiao Juying: Conducted the survey and wrote the manuscript.
Shahzada Sohail Ijaz and Ayaz Ahmad: Conducted the survey and managed local support for the survey.
An Shoshan: Interpreted the data and supervised the study.
Muhammad Ansar and Qaiser Hussain: Provided local information during survey.
Mah-Noor Azad: Conducted the survey and and helped in editing the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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