Technology for Conservation of Soil and Water Resources in China

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Abstract

According to our long-term practical experience, the technological system for soil and water conservation in China should include mainly three aspects: technology for soil erosion research, engineering technology and biological technology for soil and water conservation. The technologies for soil erosion research include technology for slope runoff (solid and liquid) measurement, artificial rain simulation for soil and water loss measurement and monitoring of soil moisture dynamics, use of Cesium-137 for measuring underwater silt and sand deposition and soil loss, use of remote sensing and GIS, and technology for small river basin harnessing. The engineering technologies for soil and water conservation include technology for gentle and bare slope rehabilitation in the hilly regions, technology for making stony-hill land green, technology for colluvial deposit management, technology for alleviating mud and sand hazard, and technology for setting up erosion prevention systems in gully and sloping regions as well as around roads, etc. The biological technologies for soil and water conservation include erosion control in gullies by planting crops resistant to infertile soils and on sloping land by planting biological fences, technology for developing biologically and economically sound reserves in eroded area, water conservation in sloping cultivated land through intercropping and under-crop sowing, technology for making land green by planting microorganism-inoculated green manure crops, and technology for designing sight-seeing areas in eroded regions by planting special crops, etc. All the above technologies may bring about beneficial effects on soil and water loss prevention if used comprehensively.

Introduction

China is one of the countries which experience the most serious soil and water loss in the world. Currently, the total area of water and soil loss (water erosion) in China amounts to 170 Mha, which covers one-sixth of the total land area of the country, and the annual loss of soil is up to 5.0×10^9 t accounting for one-twelfth of the world's total. As a result, serious land degradation is taking place in some regions of the country.

Great achievements in soil and water conservation have been obtained since the foundation of the new China. By 1990, a total of 58 Mha[1] erosive land had been improved through comprehensive measures all over the country, resulting in a saving of about 1.8×10^{10} m^3 water and reduction of 1.1×10^9 t soil loss annually.

To control soil and water loss, China enacted the Soil and Water Conservation Law, to

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[1] M of Mha indicate million.

emphasize the prevention, monitoring and management of soil and water loss, and to promote sustainable development with a view to adopting a harmoniously cycling ecosystem, through the application of systematical technologies for soil and water conservation.

In the Yangtze River region and the southern part (218 M ha), the land experiencing soil and water loss covers an area of 60 M ha (or 35% of the country's erosive land). The annual loss of silt and sand from this region amounts to half of the country's total of which, 6.7×10^8 t/yr is discharged from the Three Gorges region. To control soil and water loss in the red and yellow soil regions in southern China and in the Three Gorges region (6 M ha), the Institute of Soil Science, Academia Sinica, has carried out numerous studies for a long time. In this paper some of the basic experience in soil and water conservation obtained from the above regions is introduced.

Technologies for soil erosion research

Soil erosion is the major issue of soil and water loss, and it is also the main cause for ecological environment deterioration and land degradation. The current technologies for soil erosion research have benefited greatly from the development of the new disciplines. Basically, they can be summed up as follows:

1 Estimation of soil loss amount due to water erosion

According to the SLEMSA model constructed by H. A. Elwell, the factors affecting soil erosion such as climate, crops, soil and topography will be analyzed, respectively. The framework for the model of erosion factors is as follows:

Topographic factor—Slope gradient [S], Slope length [L]—Topographic ratio[X]——Soil factor—Erodibility [F]

Climate factor—Rainfall energy [E]——Soil loss from bare soil [K]

Crop factor—Energy intercepted [I]——Soil loss ratio [C]

Soil loss from cropland on sloping ground Z=KCX [t/ha/yr]

Using the SLEMSA model and the above-mentioned factor calculation, the amount of water lost by erosion in a certain region could be calculated. The results will be compared with those of soil loss on the spot.

1) Estimating soil loss in Kaixian county, Sichuan Province

According to previous research data, the average slope gradient in the region is 20° and slope length 30 m. Based on the calculation, K=187.7, SL=6.61, C=0.037, soil loss amount Z =42.78 t/ha/yr, equivalent to 4,278 $t/km^2/yr$.

2) Estimating soil loss on farmland with a gentle slope in the central part of Heilongjiang Province

Field investigation shows that the hilly cultivated land in the central part of Heilongjiang province has experienced a soil loss of 2,000–3,000 $t/Km^2/yr$. The soil loss amount could be calculated by the equation $Z=KXC\ 2=44.76\times9.969\times0.05=22.0$ [t/ha/yr]. When gully erosion occurs, fs=−3.0, F=1.5, Z=8,184 [t/ha/yr]..

3) Soil loss in purple soil region of Yangtze Three Gorges

Major soil on sloping farmland in the region is purple soil. The calculation of soil loss is as follows: $Z=KXC=214.3\times0.0103\times7.2=1{,}589$ [t/km^2/yr].

2 Research on the amount of loss of surface soil and sediment into the Yangtze River Three Gorges

The results indicate that the average amount of soil loss on the slope surface can reach 3,094 t/km^2/yr, and the amount of incoming sediment into the Yangtze River reaches 895 t/km^2/yr (the total amount is 40 million tons per year). The average sediment delivery ratio is about 0.28. The soil loss equation is as follows:

$A=0.8351\times R\times K\times Ls\times C$-2.3

3 Preliminary study on regional prediction equation of soil losses

A prediction equation for soil loss can be derived by numerical analysis of the data from the experimental plots on eroded red earth developed on granite in southern China. The equation is $Al=4\times Y\times K\times Ls$, where Al is the amount of soil loss; Y is the rainfall (rainfall intensity); K is the erodibility and Ls is the gradient length of the slope. This equation could be used for predicting the amount of soil losses in the granite region of southern China.

4 Computer simulation for soil and water resources in a basin

This kind of work can not be carried out without the use of mathematical models. Taking the SWRRB model [basin-scale simulation model for land and water resources management] as an example, about 200 mathematical equations are used to describe the complex relations between the various factors and processes within a basin. Among the outputs, the water yield [runoff], sediment yield, peak flow, soil water, total biomass, evapotranspiration, etc. are more important. These data can be output yearly, monthly, even daily depending on the needs. In this context basin simulation is a continuous simulation of dynamic changes.

In our research in southern China, we will compare the predicted with the measured values for the sediment yield. This study is still underway. The computer simulation for soil and water resources in a basin is just being carried out both in China and abroad. It will play an important role in research on soil erosion and water conservation, soil and water resources, ecology and environment and in the development of sustainable agriculture.

5 Cesium-137 method and magnetic susceptibility of soil in relation to quantitative research on land degradation (Dr.Pu li-jie, 1997)

1) The results obtained in Fujian [subtropical zone] indicate that; ⓐ Plot of Cesium-137 inventory [Y] against slope angle [X] shows a strong inverse relation [$r=-0.79$] and the regression equation is expressed by $Y=3{,}876.299-172.81X$, indicating that more erosion [lower Cesium-137 inventory] occurs on steeper slopes; ⓑ Average soil losses [thickness of top soil per year] in the past 30 years for arable slope crest, arable slopes and tea plantation slopes were 1.6, 10.4 and 8.0 mm/year respectively, ⓒ The surface layer enrichment factor of magnetic susceptibility [Y] in soil also shows an inverse relation with the slope angle [X] and the regression equation [$r=-0.55$] is expressed by $Y=132.03-1.65X$. The results indicate a similar tendency to that of Cesium-137 against the slope angle.

2) The results obtained in Xinjiang [temperate zone] revealed that; ⓐ The average soil loss

rates in the past 30 years for barren land, arable land and grassland amounted to 5,987.21, 3,537.29 and 3,171.31 t/km^2/year, respectively. ⓑ The average soil loss rate in the whole research area was about 3,954.06 t/km^2/year which corresponds to the medium class.

The results could be applied to similar environments in further research, although the calibration between the Cesium-137 inventory and the estimates of soil erosion rates could be further analyzed.

6 Study on erodibility factor K of subtropical soils

We have studied *in situ* the erodibility (K) of seven different types of soils in subtropical China in bare land plots under natural rainfall by this classical method. Results show that the K value varied markedly from type to type, with that of the purplish soil and cultivated red soil derived from red sandy stone being the highest, about 0.441 and 0.438, respectively, and that of the red earth derived from quaternary red clay being the lowest, about 0.104, even less than 1/4 of the former. These results indicate that under the same erosion external conditions, erosive degradation readily affects the purplish soils and cultivated red soils derived from red sandy stone, unlike the red earth soils derived from quaternary red clay, the erosive degradation ratio of the former being more than 4 times that of the latter.

In the study processes of red soil degradation in southern China, the changes of soil degradation in time and space follow erosion models, namely A-KRLSCP [the universal soil losses equation in USA]. In the equation, since the changes of the K value occur in the same soil type, the change of A in time and space depends mainly on the changes of CP factors [plant cover, management factors]. Therefore, we can determine the distribution patterns of the K value in southern China based on the soil properties [such as soil organic matter content, soil particle composition, soil granular structure, soil permeability] because the relation between the K value and soil properties is very close.

7 Characteristics of degradation of eroded soil in quaternary red clay region

The Al_2O_3 content of soil mass in intensively eroded soils is higher than that in slightly eroded soils, but its activity is lower obviously. The available water contents in slightly, extensively and very extensively eroded soils are quite different, 135, 125.5 and 61 g/kg, respectively. The proportion of water which is not readily available for use by plant to the available water is higher in the extensively eroded soils, and lower in the slightly eroded soils. Moreover, with the aggravation of soil erosion, acidification, deterioration of soil structure and depletion of nutrients result in the obvious degradation of soil .

Combined engineering and biological technologies for soil and water conservation

1 Measures and advantages of soil and water conservation in the eroded red soil region of Jiangxi province

There are about 50 M ha of eroded red soil in southern China, of which, the soils in Jiangxi province are representative in all aspects. According to an experiment conducted on about 10 ha of eroded land by the members of the Red Soil Ecological Experimental Station, significant benefits were obtained after three years of comprehensive improvement. The first step was to use engineering-biological combined measures, which include building up check dams in deep valleys, constructing horizontal table lands on 30-40° slopes, digging nutrient dibbings and then sowing difffrent plants on slopes more than 40° in declivity, planting *Lespedeza formosana* on general slopes, *Robinia pseudoacacia* on horizontal platforrns, and *Pennisetum purpureum* and *Eucalyptus camaldulensis* in the bottom. Combined plantation of arbors, bushes and grasses, coniferous and broad-leaved trees, leguminous and non-leguminous plants is also important. Secondly, fertilization should be emphasized. Generally, about 375-750 kg of phosphorus fertilizer per hectare should be added when planting *Lespedeza formosana*, and 25 kg wastes per tree should be used on the surface when planting arbors. Meanwhile, much attention should be given to water management. After three years of such practices, more than 80% of the slopes became green and the slope loss was controlled within 1 00 t a year per Km^2. A 2 cm litter layer appeared and about 20 mm rainfall was expected to be maintained. The amount of soil hydrolyzable N increased from 30-60 mg/kg at the beginning to 70-90 mg/kg. It is estimated that the total capital outlay can be recouped in 6-8 years.

2 Benefits of soil and water conservation in quaternary red soil

Planting of *Lespedeza bicolor* for soil and water conservation in red soil which showed intensive gully erosion and an exposed plinthite is very beneficial. The branches and leaves of *Lespedeza bicolor* after two years of growth reached 26 t/ha ; the amount of soil loss in the controlled area was only 1.4% of that of the check area; (the runoff coefficient was only one-third). In summer after a saturating rain the period of drought tolerance was about one week in the 0-20 cm soil layer ; two weeks in the 20-40 cm soil layer and four weeks in 40−60 cm soil layer. The functional relation between soil moisture content and time can be obtained. After improvement of the soil by biological methods, the organic matter content in the surface soil tended to increase ; the content of hydrolyzable nitrogen increased obviously (2-3 g/kg) and that of available phosphorus increased slightly more. Therefore, it can be seen that the overall benefit of greening eroded sterile soil is rapid, while the direct economic profit is not conspicuous.

3 Soil and water conservation benefits from the eroded, inferior red soils in Zhaoan county, Fujian province

From 1984 to 1991, a lychee garden of 680 ha was built in the eroded, inferior red soils. Now, an income of 840,000 yuan RMB can be obtained while the soil erosion modulus has been reduced by 89% and the soil organic matter content increased from 2.2 g/kg to 6.5 g/kg. The measures employed included the construction of terraced fields, irrigation and drainage facilities, sowing of under-crop green manure and enforcement of field management.

4 Technologies and benefits of soil and water conservation in Xingguo county, Jiangxi province

A total of 0.19 Mha land in this county experiences soil and water loss, and the loss of silt and sand reaches a value of 11.1×10^6 t. Based on studies carried out for more than 20 years, engineering and biological measures must be used jointly to control soil and water loss from this granite-derived, eroded soil. Such measures include, for example, the establishment of high-grade horizontal platforms, planting of arbors, bushes and grasses in a reasonable proportion while developing coniferous and broad-leaved mixed forests. Meanwhile, efforts should also be devoted to planting cash crops such as tea, Chinese chestnut, oil tea, fruits and herbs. Currently, the loss of silt and sand countywide, has been reduced by 6.4 Mt and the soil water-holding capacity has been increased by 8.8%. Soil-conserving efficiency has reached 64.2%. The total value of agricultural and industrial production in 1992 increased by 1.4 times as compared with that in 1982. For agriculture, the increase reached 88.3%. Large ecological, economical and social benefits have been achieved.

5 Soil and water loss control in regions dominated by colluvial granite deposits in Guangdong province

There are about 2,300 ha of mountain-hill land in Wuhua, Guangdong province, of which a large part is covered by colluvial granite deposits. By adopting comprehensive measures for more than 20 years, the situation has been basically improved. Improvement measures included planting of water-conserving forests on top of the hill, mixed forests in the middle, subtropical fruit trees and pasture in the bottom and on the level lands, efforts were made to promote fishery, poultry and livestock-raising as well as cultivate tea, herbs and establish bamboo plantations. Meanwhile, check dams were built up on valley beds. Currently, the production value per ha from this land is as high as 60,000 yuan RMB and the rural economy as a whole is developing faster than ever before.

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