

Article ID: 1001-0742(2000)01-0090-08

## Soil and water loss in the Lancang River-Mekong River watershed (in Yunnan section, China) and its control measures

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**Abstract:** According to a lot of hydrological and environmental monitoring data, the condition of soil and water loss in the Lancang River-Mekong River watershed (in Yunnan section, China) is described. The occurrence and development of soil and water loss is analyzed. The conclusion is that: (1) generally, the situation of soil and water loss in the Lancang River-Mekong River watershed (in Yunnan section, China) is light, however, soil and water loss in some regions is serious, especially in the middle reach area of the river; (2) soil and water loss in the Lancang River-Mekong River (in Yunnan section, China) watershed presents developing tendency and it is mainly caused by human beings. In accordance with these results, the control measures for soil and water loss are discussed.

**Key words:** Lancang River-Mekong River watershed (in Yunnan section, China); soil and water loss; control measures; soil erosion; mud-rock flow; landslide

**CLC number:** X522      **Document code:** A

Mekong River is originated in the northern range of Tibet-Qinghai Plateau of China, flowing through six countries, they are China (Yunnan Province), Myanmar, Laos, Thailand, Cambodia, and Viet Nam, the total length of the river is 4880 kilometers, and the catchment area is 7950 thousand square kilometers. Thanks to the development of comparative political and economic situations and the enhanced co-operations among various countries in this area, the emphasis has been put on the Mekong River watershed area in researching, development, and investment by riparian and many non-riparian countries and regional organizations. Internationally, Mekong River has become a new hot spot. The section of Mekong River in China, namely the Lancang River, accounts for 1/4 length of the river, thus the environmental conditions in the upper reach area of Mekong River are crucial for the development and investment in the whole watershed area. Generally, the environmental qualities in Yunnan section of the river is good, soil and water loss is light, however, with the increasing population pressure and economic development in the relevant watershed area in China, soil and water loss become more and more serious, especially, landslide and mud-rock flow induced by soil and water loss have been occurring sporadically. The further worsening of this situation will have negative impact on the sustainable environmental conditions and economic development in this area, and also in the whole watershed and countries in the lower reach area of Mekong River. More attentions have been attached in soil and water loss conditions of the Lancang River both domestically and internationally. Soil and water conservation in Lancang River watershed (Mekong River in Yunnan section, China) is vital to environmental conditions both in Yunnan Province of China and in the lower reach countries, i. e., Laos, Myanmar, Thailand, and Viet Nam, since some large-scale cascade hydroelectric stations and much more development projects have been planned or have been under construction along Mekong River.

# 1 The current situations of soil and water loss and its relevant impacts

## 1.1 The current situations of soil and water loss in the Lancang River watershed

### 1.1.1 The current situations of soil and water loss and its characteristics

There are six major river systems in Yunnan Province, they are Lancang River (Mekong River), the Nanpan River (belongs to the Pearl River water system), Irrawaddy River, Nujiang River (Salween River), Jinsha River (the Yangtze River), and Yuanjiang River (Honghe River) respectively. Soil and water loss in Lancang River (Mekong River) is comparatively light, soil erosion rate is 28.6%, lower than the average rate in Yunnan Province (39.19%, Table 1). Compared with other major water systems in Yunnan, sediment discharge, soil erosion modulus (the annual soil erosion volume per square kilometer), soil erosion speed (the thickness of annual loss of layer soil) in Lancang River are low, they are 84.6 million tons/a, 1095 tons/km<sup>2</sup>, 0.55 mm/a, respectively, and the annual soil erosion volume is 28.0729 million tons. Generally, soil and water loss level in the watershed is comparatively low.

**Table 1 Soil erosion conditions in six major water systems in Yunnan, China**

Watershed	Catchment area, km <sup>2</sup>	Silt transportation volume, million tons/a	Erosion modulus, tons/(km <sup>2</sup> ·a)	Erosion speed, mm/a
Lancang River (Mekong River)	88715.44	84.6	1095	0.55
Nanpan River (the Pearl River)	57328.63	23.15	397	0.32
Irrawaddy River	19057.84	17.13	912	0.73
Nujiang River (Salween River)	33421.26	28.42	849	0.68
Jinsha River (the Yangtze River)	109821.72	106.12	973	0.78
Yuanjiang River (Honghe River)	75179.99	89.05	1190	0.95
Yunnan Province	383390.11			

Source: surface water resource in Yunnan Province, 1984, The Master-Plan of the construction of protection forest system in Lancang River watershed in Yunnan, 1994

However, in some areas, due to frequent economic activities of human beings, and damage of forest vegetation, the ecological environments have shown the tendencies of deterioration, soil and water loss is prominent, having lead to geographic disasters such as mud-rock flow and landslide (Table 2).

**Table 2 Collapse, landslide, and mud-and-rock flow disasters in the Lancang River watershed**

Type	County towns*	Townships and factories*	Highways*	Hydroelectric power stations*	Reservoirs*
Yunnan Province	30	23	2220 km	41	39
The Lancang River watershed	13	8	946 km	27	19
% of Yunnan	43.3	34.8	42.6	65.9	48.7

\* Hit by disasters; Source: planning research in the Lancang River watershed in Yunnan Province, 1994

### 1.1.2 Soil erosion areas

Soil erosion intensity is referred to the fact that whether soil loss amount per unit area in a certain area is up to or surpass the allowable amount. Soil erosion intensity that indicates the comprehensive situations of soil erosion in this area is an average value in a certain area. In our research, according to the national classification standard of soil erosion intensities in China, combined with the soil erosion and soil erosion modulus in various counties, soil erosion in the watershed is classified into micro-erosion (soil erosion modulus < 500 t/(km<sup>2</sup>·a)), light soil erosion (soil erosion modulus, 500—2500t/(km<sup>2</sup>·a)), intermediate soil erosion (soil erosion modulus, 2500—5000 t/(km<sup>2</sup>·a)), strong soil erosion (soil erosion modulus, 5000—8000 t/(km<sup>2</sup>·a)), and

ultra-strong soil erosion (soil erosion modulus, 8000—15000 t/(km<sup>2</sup>·a)). While, light soil erosion is reclassified into light soil erosion I (soil erosion modulus, 500—1000 t/(km<sup>2</sup>·a)), light soil erosion II (soil erosion modulus, 1000—1500 t/(km<sup>2</sup>·a)), light soil erosion III (soil erosion modulus, 1500—2500 t/(km<sup>2</sup>·a)). Currently, soil erosion area in the watershed is 25746.59 square kilometers, covering 28.60% of the total area of the Lancang River watershed. Among them, the light soil erosion area, the intermediate soil erosion area, and the strong and the ultra-strong soil erosion areas are 16738.81, 8378.73, and 629.05 square kilometers respectively. The average annual soil erosion volume is 2.80998 million tons, the average soil erosion modulus is 1091 tons per square kilometer, and the annual sediment discharge is 84.60 million tons.

In the whole Lancang River watershed, soil and water loss in the middle reach area is the most severe, while soil and water loss in the lower reach area are the lightest. Soil erosion rates in the upper reach area, in the middle reach area, and in the lower reach area are 29.46%, 34.40% and 25.06% respectively. In 31 counties in the watershed, the differences of soil erosion rate are evident, soil erosion rate in Menglian County is the minimal (14.17%), while that in Nanjian County is the maximal (42.14%). Nanjian County and Shuangjiang County, the two counties with soil erosion rates higher than the average soil erosion rate of Yunnan Province, are located in the middle reach area, and all of the 15 counties with soil erosion rate higher than the average soil erosion rate of the Lancang River watershed are those in the middle area, accounting for 80% of 19 counties where soil erosion rates are higher than the average rate of Yunnan Province (Table 3, Fig. 1).

**Table 3 Soil erosion rates in the Lancang River watershed (Mekong River in Yunnan section, China)**

Soil erosion rates	<10%	10%—20%	20%—30%	30%—40%	>40%
The upper reach area		Weixi, Lijiang		Deqing, Lanpin	
The middle reach area			Yangbi, Jianchuang	Dali, Yinglong, Eryuan, Weishan, Yongpin, Baoshan, Changling, Linchang, Fengqing, Yunxian, Gengma, Cangyuan, Jingdong	Nanjian, Shuanjiang
The lower reach area	Jiangcheng	Simao, Lancang, Puer, Zhengyuan, Menglian	Jingu, Mengla	Jinghong, Menghai	
Soil erosion area, km <sup>2</sup>	47.75	3363.32	5111.19	16077.09	1147.24
Percentage of the total area, %	0.19	13.06	19.85	62.44	4.46

### 1.1.3 Sediment concentration

The seasonal variations of sediment concentration are closely related to the seasonal variations of precipitation and runoff volume in the watershed area. The periods with large sediment concentration are mainly concentrated within flooding seasons. Generally the months with the maximal sediment concentration are concentrated from June to August, and the sediment discharge within these four months when the sediment discharge is maximal accounts for 80%—90% of the total annual silt transportation amount. The average sediment discharge of the Lancang River (Mekong River) in Yunnan Province is 61.25 million tons, and the average annual sediment concentration is 0.57—1.35 kg/m<sup>3</sup>.

In the north of Gongguo Bridge (located in the Yongping County in the upper stream area of Lancang River), the impact of human beings' activity is minimal due to the boisterous stream, deep water in the stream, and sparsely distributed population. The annual average sediment concentration is 0.73 kg/m<sup>3</sup>, the annual sediment discharge is 21.40 million tons. In the south of Gongguo Bridge, the annual sediment discharge is 63.20 million tons, accounting for 75% of the

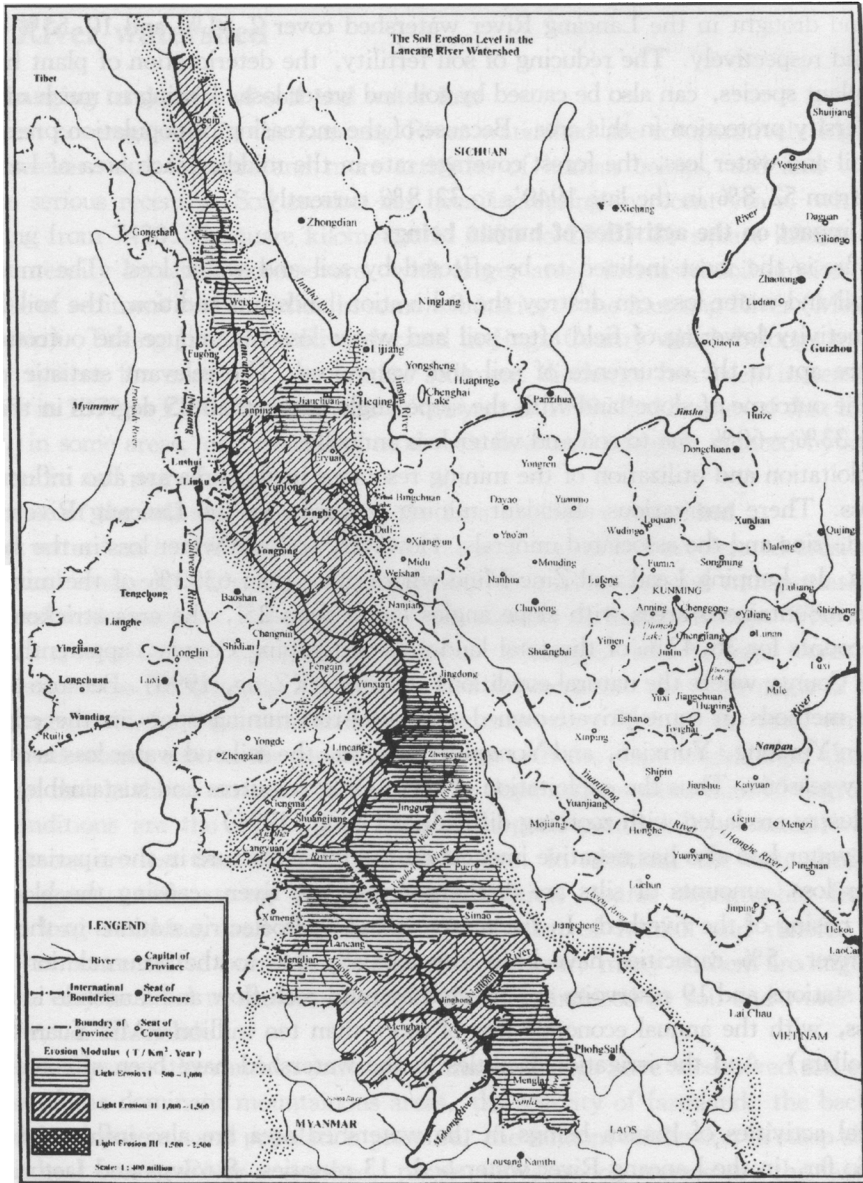


Fig.1 Soil erosion level in the Lancang River-Mekong River (in Yunnan section, China) watershed  
The international territories and disputed boundary in the map are in accordance with the concerned international agreement

total annual silt transport volumes in the whole watershed area.

## 1.2 The impact of soil and water loss in the Lancang River watershed

### 1.2.1 The impact on natural environment

Soil and water loss can cause the loss of surface soil layer, encroaching of the rocks, and the instability of the homogeneous stratum, and thus lead to geographic disasters, such as mud-rock flow apt to occur. In the counties or towns affected by mud-rock flow and landslide, such as

Lanping, Deqing, Gengma, Baoshan, Dali, Lanjian, Yunxian, and Zhangyuan, soil erosion rates are larger than 30%. Flooding and drought are induced by soil and water loss. The areas stricken by flooding and drought in the Lancang River watershed cover 2.61% and 10.55% of the total cultivation land respectively. The reducing of soil fertility, the deterioration of plant habitats, the reduction of plant species, can also be caused by soil and water loss, leading to much more pressure on the biodiversity protection in this area. Because of the increasing of population pressure and the severing of soil and water loss, the forest coverage rate in the middle reach area of Lancang River has declined from 52.8% in the late 1940's to 32.8% currently.

### 1.2.2 The impact on the activities of human beings

Agriculture is the most inclined to be affected by soil and water loss. The mud-rock flow induced by soil and water loss can destroy the cultivation lands, in addition, the soil fertility loss and the productivity lowering of field after soil and water loss can reduce the outcome of crops. Slope lands are apt to the occurrence of soil and water loss. The relevant statistic results have shown that the outcome of slope land with the slope angle larger than 25 degrees in the watershed is reduced by 33%—60% due to soil and water loss annually.

The exploitation and utilization of the mining resources in this area are also influenced by soil and water loss. There are various abundant mining resources in the Lancang River watershed, especially lead, zinc and the associated minerals. However, soil and water loss in the major mining area is serious. In Lanping Lead and Zinc Mine where more than 63.3% of the mining spot are located in the mountainous areas with slope angles larger than 25°, the area stricken by soil and water loss accounts for 36.42% of the total land area of Lanping County, apparently larger than that in Weixi County where the natural conditions are similar (Zeng, 1996). Because of the out-of-dated mining methods in some private-owned and rural-run mining spots in the exploitation of copper mine in Yunlong, Yunxian, and Yongping counties, the soil and water loss is comparatively severe in rainy seasons. Thus the exploitation of the mining resources and sustainable development of mining industry are laden with zooming difficulties (Zeng, 1996).

Soil and water loss also has negative impacts on the infrastructure in the riparian areas. With soil and water loss, amounts of silts are discharged into the river, causing the blockage of the reservoir and raising of the riverbed. In the reservoir and hydroelectric stations in the upper reach areas of the river, 5% capacities have been lose annually due to the accumulation of silts. 27 hydroelectric stations and 19 reservoirs are affected by mud-rock flow and landslide induced by soil and water loss, with the annual economic loss of more than ten million RMB Yuan (about 1.21 million US dollars). And the irrigation facilities in the watershed have been affected by soil and water loss.

The social activities of human beings in the watershed area are also influenced by soil and water loss. So far, in the Lancang River watershed, 13 counties, 8 towns and factories, and 946 kilometers of highway have been stricken by soil and water loss.

The booming tourism in this area is also threatened by soil and water loss. There are three national key landscape areas and many nature reserves in the Lancang River watershed, and the first navigation and the first aviation tourism belt in China will be formed after the establishment of the cascade hydroelectric stations in the trunk of Lancang River. However, the value of this golden tourism belt will be greatly lowered if soil and water loss become severe in the future.

In addition to the above, the developing of soil and water loss in the Lancang River watershed (Mekong River in Yunnan section, China) will affect agriculture production, irrigation engineering, and hydroelectric engineering, and so on. In the lower reach counties, which will have negative impact on the sustainable development in the whole Mekong River watershed.

## **2 The changing tendencies and the causes of soil and water loss in the Lancang River watershed**

### **2.1 The changing tendencies of soil and water loss**

The forest coverage rate in the Lancang River watershed are comparatively high in Yunnan Province, however, due to more and more activities of human beings, soil and water loss has become more serious recently. Soil erosion has been increasing in recent years, with soil erosion area increasing from 7420.84 square kilometers in 1986 to 25633.80 square kilometers in 1993. Soil erosion intensity becomes more severe, with larger area, increased soil erosion volume, and sharp increase of sediment concentration in some tributaries of the Lancang River (Mekong River in Yunnan section). Taking Jingudahe River located in Jingu County which belongs to the Lancang River water system for example, the annual sediment discharge has been increased from 706 thousand tons in 1977 to 1780 thousand tons in the year of 1990, 2.52 times of that in 1977. More importantly, in some areas, occurrences of mud-rock flow and landslide induced by soil and water loss become more and more frequent.

### **2.2 The cause of the soil and water loss in the Lancang River watershed**

Soil and water loss in this area is caused by natural erosion and accelerated erosion.

The natural erosion is the process of dissociation, jeopardization and transportation of the soil surface material under tectonic forces without the influence of human beings. The major causing factors include precipitation, topographic features, lithotype, and tectonic constitution. The topographic features in the Lancang River watershed are complex, the slope angle of hypsographic features are large, and the mountainous areas cover more than 95% of the total watershed area. Statistically, soil erosion rate in the mountainous area with the slope angle larger than 25 degrees are larger than that in the mountainous area with the slope angle smaller than 15 degrees in the case that other conditions are the same. The areas with good permeability, erosion resistance and washing-resistance are less than 20% of the whole area. In addition, the watershed is located in various fault areas, with strong architectonic activities, sparse topographic features, large precipitation, long sunshine, and the random distribution of rainfall and runoff. 80% of the precipitation are concentrated from May to August every year, many of them are lingering storms, some areas are very inclined to the occurrence of disasters induced by soil and water loss, such as mud-rock flow, and landslide.

In the recent years, the random activities of human beings have accelerated soil erosion in this area. Because of the dominant mountainous areas, the scarcity of farmland, the backwardness of the economic development, and population pressure, the random cultivation in steep slopes are very frequent. In the Lancang River watershed, plane cultivation on terrace are the least, while the straight plowing in steep slopes and contour cultivation are more than 80%. Soil during spring is dry, after cultivation, the soil surface is bare, a storm in raining season usually causes prominent soil and water loss. In addition to the above, the slashing of the forest and the inducing reduction of forest coverage rate are also the major cause of soil and water loss. Due to the lack of fuel in rural areas and the inconvenience of communication condition in remote mountainous areas, wood is still the major material of ordinary life and even production in rural areas, thus it is a very time-consuming and nervous process for the eliminating of this dilemma. The booming of town and township industry in recent years, the mining industries depending on the abundant mining resources in this region, and the poor management in some mining spot have made the forest destroyed. In addition, most of the discharges are not well treated, causing the deterioration of soil layers, and sporadic occurrences of mud-rock flow and landslide.

### **3 The control measures of soil and water loss in the Lancang River watershed**

#### **3.1 Planning and strengthening of implementation**

Considering soil and water loss conditions, and economic development, and resource exploitation planning, classify the area into some management and control areas, and drafting the plan for the aim and methods of soil and water conservation and implementation plan for the control of tributaries in the watershed. By combining of short-term and long-term planning, this plan should be included in the economic plans of governments in various levels, thus soil and water loss will be controlled efficiently.

Enhance soil and water conservation works, establish the network for soil and water conservation, strengthen the law enforcement, implement soil and water protection law, and implementation rule of soil and water conservation law, draw up the implementation of soil and water conservation law in Yunnan Province according to local conditions.

#### **3.2 Intensify prediction and protection**

Because of the comparatively light soil and water loss situations in the Lancang River watershed, and the comparatively large area hit by soil erosion and the economic potentials of both Yunnan Province and P. R. China, the emphasis of soil and water conservation should be put on the prediction, prevention, and the strengthening of the conservation.

The population growth must be controlled strictly, soil and water conservation should be strengthened, and ecological engineering should be implemented. The population growth is crucial for the forming of the vicious circle of soil and water loss. In the areas stricken by soil and water loss, especially those in the middle reach areas, family planning policies, population emigration policies, and employment policies should be strictly implemented to control the population growth, improve the population quality, and intensify soil and water conservation. The policy-makers in various levels of the government should clarify the priority of prediction and protection, which is vital since controlling is more difficult while the destroying of the soil and water resource is much more apt to happen. Even much more investment and human resources will never contribute to the apparent results of controlling work if prediction and prevention work can be well done. In the process of resource exploitation and the construction of middle-scale and large-scale enterprises, soil and water conservation plans must be made. Which should include forest protection, landfill for discard, soil conservation, reforestation and soil and water conservation measures, which should be designed and constructed simultaneously with the principal part of the projects. In addition, comprehensive engineering methods should be carefully considered in the design and construction of a series of cascade reservoirs and cascade hydroelectric power plants in development plan in the riparian area of Lancang River-Mekong River. These methods include building of silting retention facilities, filtering of silt with man-made engineering projects, building protection forest belts in the catchment area, and dredging-up of riverbed and cascade reservoirs bottoms in some parts of river.

Forest reduction is one of the major causes of soil and water loss, the construction of protection forest system has been proved the effective methods for the control of soil and water loss in the whole watershed area. In the trunk stream and tributaries of the Lancang River, protection forest system should be established for the effective protection of soil and water. The planned protection forest system in this area needs the investment of 1.25 billions RMB Yuan (about 150.5 million US dollars), with the increased forest area of 1.06 million hectares. Forest coverage rate in the Lancang River watershed will be increased from 38.3% to 50.0%, while soil erosion rate will be decreased from 28.6% to 18.2%, thus the effective control of soil and water loss will be achieved.

Attentions should also be paid to vegetation rehabilitation that has been proved important in the effective reducing of soil and water loss in the degraded ecosystems in tropical and subtropical areas (Yu, 1996).

### 3.3 Control of the key areas

Due to the fact of serious soil and water loss and the potential dangers in some areas, some key areas should be controlled more intensively. In accordance with the different conditions such as slope angles, soil textures, and others, etc., different methods should be used for the construction of farm land. For example, in the area with the slope angle larger than 15 degrees, the slope lands should be changed into terrace. While in the gentle slope land with the slope angle between 15 and 25 degrees, contour cultivation and intercropping of crop and forest should be implemented to establish the reasonable agro-forestry system. The steep slope lands where the slope angle larger than 25 degrees will be free from cultivation, and be returned to the forest land.

Landslide and mud-rock flow are occurring frequently in some areas where soil and water loss is serious, the priority should be put in the areas apt to be stricken by the disasters, particularly the location of towns, mines and factories. In addition, control in the tributaries should be emphasized to make sure effective working of hydroelectric stations and reservoirs and also their securities. The Deqing and Lanping counties in the upper reach area, Dali and Fengqing counties in the middle reach area should be controlled emphatically; and Baoshan, Lancang, Simao, three counties with the high occurrence frequencies of landslide and mud-rock flow, should be listed into the emphatically controlled area, with engineering methods combined with biological methods, effective controlling should implemented for some key projects.

### 3.4 Strengthening international cooperation

As an important international river in Asia, international cooperation and coordination should be strengthened among riparian countries and with some international organizations in the study and control in environmental protection in the whole watershed area of Mekong River. International technical and financial supports should play important role in the control of soil and water loss in this region.

Control of soil and water loss in the Lancang River watershed will contribute to economic development of various riparian countries in the whole Mekong River watershed. Soil and water conservation in the Lancang River watershed (Mekong River in Yunnan section, China) is significant both economically and politically.

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