

A study of land degradation and restoration in mountain environments in Liaoning Province

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Abstract Liaoning Province lies in the south of the northeastern region of China. Under the special geomorphological and geological conditions found in the mountains in this region, the local climate, coupled with irrational human activity, result in severe weathering and denudation of the land surface, and land degradation. Consequently, problems such as disastrous erosion, and debris flows occur frequently and are increasing. As the ecological environment degenerates; soil fertility declines and land productivity decreases over wide areas. Serious land degradation has restricted development of the regional economy and social improvement. In this paper, both the factors influencing the occurrence of land disasters, such as disastrous erosion and debris flows, and the feedback relationship between the effect of such disasters and the development and exploitation of the region are considered. Based on such work we present proposals for the improvement of the mountain environments in this region as a means of improving social conditions and strengthening the local economy.

REGIONAL CHARACTERISTICS

Liaoning Province is located in the south of the northeastern region of China and stretches from 118°53'E to 125°46'E in longitude, for a distance of 574 km. In a north-south direction the latitude spans 38°43'N to 43°26'N, which amounts to 530 km. The relief declines from the north to the south and from the eastern and western margins to the centre. In the eastern and western areas there are mountains and hills. Based on their landforms, these can be divided into four parts, namely, the eastern Liaoning Mountains, the Liaodong Peninsula Hills, the western Liaoning Low Mountains and Hills and the northwestern Liaoning Low Hills. Overall they cover 108 722 000 ha or 60% of the total area of the province. Thirty percent of the province is occupied by plains.

With reference to geological structure, most of this region belongs to the China-Korean Qiasi-platform, although the northern margin belongs to Tianshan-Xingmeng geosyncline folded zone. The crust is active and faults are

distributed widely and well developed. The region experiences a monsoon climate influenced by altitude, the land-sea distribution and the atmospheric circulation. The annual average temperature is 5-10°C and the maximum range of temperature from the south to the north is no more than 5.6°C. The annual range is 30-40°C. Precipitation is influenced by the prevailing westerlies and the annual average varies from 400 to 1100 mm over the whole region, decreasing from the southeast to the northwest, with great temporal and spatial variation. In summer, high intensity rainfall occurs and surface runoff is intense. Mountains hazards in this region, which mainly include soil erosion, debris flows, rockslides and avalanches, result in serious degradation of the environment. It has become a limiting factor in the development of the regional economy and in social improvement.

A MODEL OF THE DEGRADATION OF THE MOUNTAIN ENVIRONMENT

Unfavourable natural conditions and irrational human activity have caused many land disasters, including serious soil erosion and debris flows. As a result of the aggregate effects of these disasters, soil and water losses are increasing. Consequently, the ecological environment is deteriorating. Soil fertility is decreasing and floods and droughts are occurring more frequently and getting worse. Figure 1 illustrates a model of the degrading mountain environment.

The distribution of soil and water losses in time and space

In the time dimension, erosion and debris flows of varying intensity occur each

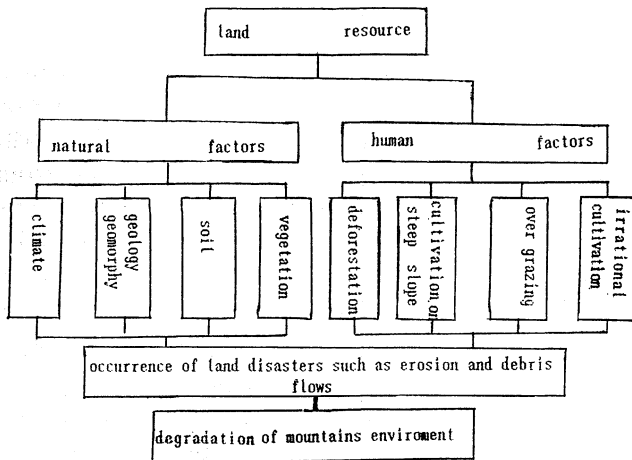


Fig. 1 The model of mountain environment degradation.

year, but they mostly occur during the flood period from June to August. Precipitation during this period constitutes 60-80 percent of that in the whole year, and intensities are always high. Soil erosion therefore mostly takes place in the summer rainy season. Data from the Fuxing soil and water conservation station show that soil and water losses in July and August made up 96% of the total losses in 1983.

In the spatial dimension, soil and water losses are most serious in the western Liaoning Low Mountains and Hills. Other areas include the eastern Liaoning Low Mountains and Hills, the western Liaoning Low Mountains and Hills and the Tiefa Hills area in the north of Liaoning. The area involved is about 575 000 ha and covers 57% of the mountain area and 40% of the province. In the worst affected western Liaoning Low Mountains and Hills, erosion rates of up to 3000-5000 t km⁻¹ year⁻¹ are found.

Erosion and debris flow characteristics

In the Liaoning Low Mountains and Hills area, soil erosion is principally caused by water. Wind erosion is of secondary importance. Water erosion includes sheet erosion, gullying and erosion caused by mountain floods and debris flows. Ordinary soil erosion (sheet erosion and gullying) is found over a wide area. For example, in Jianping County, there are over 8000 gullies, and they cover 41 000 ha which represents 8.4% of the total land in this county. Erosion associated with mountain floods and debris flows can cause serious damage. For example, in 1961 mountain floods in Chaoyang District resulted in losses worth more than 300 000 Chinese yuan in Chaoyang county city. A more extreme example are the floods of 28 July 1981, when extremely intense rainfall led to mountain floods and caused rockslides, avalanches and debris flows in more than 100 gullies and slopes on the Laomao mountain. As a result, 115 villages in six counties were affected, threatening 556 000 people and destroying 38 517 houses and 60 000 ha of cultivated land. In addition, 4.9 km of the Changchun-Dalian railway line were destroyed and transport along the whole line was stopped for four days. The total economic loss amounted to 547 000 000 Chinese yuan.

The effects of erosion and debris flows hazards

- (a) *The area of cultivated land decreases and soil fertility declines.* The net decrease in the cultivated land area over the whole province amounts to 713 333 ha since 1949. This results primarily from erosion and debris flows. Combined with the effect of population growth, the average cultivated land area per capita fell from 0.25 ha in 1949 to 0.1 ha at present. Investigations show that 69 000 ha of cultivated land were

destroyed from 1957 to 1985 and nitrogen losses associated with eroded soil are equivalent to 240 000 t ammonium bicarbonate. According to observations made in 1979 on experimental plots located in Tongyuanbao village in the eastern mountains area where the natural vegetation cover is good, soil losses were $55.5 \text{ t ha}^{-1} \text{ year}^{-1}$ in the farming land with slopes of 11° . This erosion destroyed the soil structure, and resulted in a decline not only in soil fertility, but also in the soil field capacity and in land productivity.

- (b) *Aggravation of mountain floods and droughts.* Destruction of vegetation and the soil structure reduce the soil's capacity to store water. In years with high rainfall, mountain floods are more frequent and rockslides, avalanches, debris flows and other secondary hazards are triggered causing severe damage. In drier years, droughts are aggravated. Investigations indicate that in the nineteenth century, the weather was favourable in 46 years, normal in 40 years, waterlogged in 8 years and drought in 6 years. However, in the 23 years from 1958 to 1981 the weather was only favourable in five years and in the other 18 years, it was either waterlogged or drought. From 1980 to 1984 there was a continuous drought in Liaoning Province. In the spring of 1984, in the south and west of Liaoning Province alone there were 933 333 ha of land hit by drought. One hundred and seventy out of 200 reservoirs in Chaoyang district dried up.
- (c) *Deposition in reservoirs and rivers.* Because of soil and water losses, large quantities of sediment are transported into rivers by runoff leading to blockage and aggradation of river channels reducing their ability to convey floods. Deposition of sediment in reservoirs reduces the storage. An example is provided by the Liao River. One of its tributaries, the Chen River, carries 77 100 t of sediment downstream each year. As a result deposition between the mouth of the Liu River and the Suangdaizi River has become worse and this reach has aggraded such that the bottom of the channel is on average 1-2 m above the ground. The flood discharge capacity has been reduced from $5000 \text{ m}^3 \text{ s}^{-1}$ in the 1950s to $267 \text{ m}^3 \text{ s}^{-1}$ in 1991. As a result grain production, factories and mines and transportation in the middle and lower reaches have been adversely affected.

There have been 56 medium and small scale reservoirs constructed since 1958, but 12 of these had been destroyed by 1979 because of deposition. Large and medium scale reservoirs in the whole province have lost a total of 100 000 000 m^3 capacity as a result of deposition.

- (d) *Deterioration of the ecological environment of the mountain area.* Severe erosion reduces the soil thickness, rock is exposed over a wide area, and the mountain ecological balance is disturbed. Serious gullying cuts the land into small fragments and consequently makes it difficult to farm. A typical example is provided by the area between the eastern part of the Yanshan Mountains and the Western Liaoning hills. It was once a royal

hunting area, where the forest flourished and wild animals were hunted. In the past 100 years repeated destruction has resulted in an extensive decrease of the vegetation cover. Some places in the area have changed into bare hills and mountains. Another example is the eastern mountains area. In the last 20 years floods and drought have occurred frequently and have not only damaged the agriculture in the region, but also affected the water supply to the central plain since this comes principally from the eastern mountains. Unless strong action is taken to conserve or restore the ecological balance of this mountain area, the ecological disturbance will cause serious problems.

COMPREHENSIVE RESTORATION OF THE MOUNTAIN ENVIRONMENT AND ECOLOGICAL RECONSTRUCTION

As in other regions, great attention has been paid to structures for conserving soil and water in Liaoning Province. Many years of hard work have brought 2 790 000 ha under initial control. This represents 48.6% of the degraded area. In this work 394 000 ha of terraced fields were built; 27 000 ha of land was reclaimed in gullies, and 2 140 000 ha of forest were planted for the conservation of soil and water. Many years of conservation work have alleviated the soil and water losses; with associated economic and social benefits.

Methods of reducing soil and water losses

- (a) *Engineering methods.* These include: conversion of land on slopes to fallow; orchard engineering involving planting fruit trees on slopes; building terraced fields on slopes; gully engineering, involving engineering measures to prevent gullying from getting worse (this is usually linked with biological measures); and construction of protecting banks.
- (b) *Biological methods.* This is an effective approach to conserving water, preventing erosion and assisting the development of agriculture, forestry and animal husbandry. Closing hillsides to facilitate afforestation, planting of trees and the growing of herbage are the main measures.
- (c) *Agriculture technology methods.* These include farming between ridges across the slope, intercropping in belts along the contour and planting in hollows.
- (d) *Comprehensive restoration of small drainage basins.* A small drainage basin is regarded as a unit to be comprehensively planned. A wide range of measures for conserving soil and water can be employed in the hope of obtaining combined benefits. In recent years some good results have been achieved using this approach.

Solution to the problems of the mountain environment

- (a) Accelerating the development of forestry is a strategic measure to prevent soil and water losses and ecological disturbance.
- (i) From the viewpoint of ecological improvement, environmental degradation in mountain areas results from the backward economy. In order to change the backward state, production must be adjusted so that the economic growth can be in harmony with the ecological condition of the mountain area. Township enterprises and industries which can take advantage of the resources of mountain areas, such as processing of agricultural and forestry products and production of building materials should be given priority. In this way, the quality of people's lives in mountain area can be rapidly improved.
 - (ii) Planting fruit trees and growing herbage. This is an important strategic measure for developing the economy and improving ecological conditions in mountain areas. In Liaoning Province, the forest area covers only 3 433 000 ha, or 23.5% of the total land. Statistics show that there are 1 000 000 ha of waste land which could be used for forestry. This is located in Chaoyang, Fuxing and Tieling in the west, and this is where afforestation should be concentrated in the future. In the course of afforestation, landforms should be taken into account when dealing with the mountain ecological system. Afforestation should be speeded up so that barren land can be used as soon as possible. Such work is very important to increasing the area of forest cover and maintaining the ecological balance, as well as to supplying more forestry products.
- (b) Conserving land resources and maintaining the ecological environment of the soil. From the viewpoint of the ecological environment, destruction of the land resource means that soil fertility and land productivity decline and pollution of the soil reduces the quality of agricultural production. The following are the main measures for protecting the land resource:
- (i) Adjusting the agricultural structure and the distribution of crops. Agriculture, forestry and fisheries should be developed together. The acreage of crops which can improve the land should be expanded so that the conservation of land can be integrated with its utilization. More organic fertilizer should be used in place of chemical fertilizer to increase the organic content of the soil, improve soil structure and increase its fertility.
 - (ii) Careful utilization of land resource, and integrating land exploitation with land conservation.
 - (iii) Actively exploiting rural energy resources. The planting of fuel forests should be seen as a priority. Other energy resources such

as biogas, solar energy, terrestrial heat and wind energy should also be exploited. Comprehensive exploitation of rural energy as well as its careful utilization is critical for conserving land resources and maintaining the ecological environment of the soil.

- (iv) The development of township enterprises must be scientifically administered, and environmental protection must be seen as a priority. Only in this way can the rural environment be protected from pollution.

Guidelines for comprehensive restoration of the environment and ecological improvement in the mountain areas

- (a) In the Eastern Liaoning Mountains, forestry should be seen as the principal development. Land in this region consists primarily of forest land and grass land on the slopes. Only a small area is cultivated. Special local products play an important role in the people's income. The main problem here is the dislocation of the agricultural structure. The income from forestry is too low in relation to agricultural income. It is only 30% of the latter. The secondary problems are deforestation and soil and water losses. The advantages of this area are the extensive forests and grass land and the abundant special local products. Thus, there is great potential for developing forestry. Future development in this area should be based on forestry as a dominant production area but should include expanding the area and integrating agriculture, forestry and animal husbandry. Particular importance should be allocated to afforestation around the source of rivers as well as to breeding cattle, raising silk worms and the production of flue-cured tobacco. In order to implement the above-mentioned strategy, land resources must be allocated appropriately and as follows 12% for farming; 56% for forestry; 13% for animal husbandry; and 19% for other uses.
- (b) In the Liaonong Peninsula Hills, emphasis should be placed on the development of the production of economic crops. The land resources of this region are characterized by an abundance of sunshine and warmth and a developed economy. Water resources cause a problem since they are unevenly distributed and shortages of fresh water are very severe in some places. Deforestation has resulted in severe soil and water losses and disturbance of the ecological balance. The area of cultivated land is limited and land productivity has declined. The advantages of this region lie in the excellent climate and the variety of land types, which are favourable to multiple management and integrated exploitation. Another characteristic of this region is that production of economic crops flourishes, particularly fruits, silkworm cocoons and peanuts. Orchards occupy 36.4% of the total area of the province and 77.9% of the apple production of the province is from this area. Development in this region

- should focus on the production of commodities such as fruit, cocoons, peanuts, vegetables and aquatic products; devote major effort to the planting of shelter-forests on farm land and along the coast; vigorously utilize biogas so that the crop waste can be returned to the field; and promote the growing of green manure in order to improve soil fertility.
- (c) In the western Liaoning Low Mountains and Hills area, animal husbandry should be developed as the dominant product. In this region, deforestation coupled with heavy rainfall have resulted in severe soil erosion. Natural hazards such as drought and soil and water losses occur frequently and the ecological system is disturbed. In addition, most of the area is mountainous and cultivated land is limited. In addition its productivity is very low. In addition the existing economic base lacks stability. Development of agriculture in this area should exploit the excellent climate conditions, while integrating agriculture, animal husbandry and forestry and taking agriculture and animal husbandry as the dominant areas. Soil and water losses must be controlled comprehensively by afforestation linked with engineering measures so that soil fertility is improved.
- (d) In the northwestern Liaoning Low Mountains and Hills, forestry and animal husbandry should be developed in combination. Land resources are abundant, but the population is small and the main use of land is for extensive cultivation. The potential for increasing land productivity is great. However, the land resource of this region is characterized by soil infertility and a backward economy. The main problems in this region are the disturbance of the ecological system and the severe losses of soil and water. Nearly half of the total land has been destroyed. In addition, some locations are affected by shifting sand dunes and salinization. The agriculture structure is poorly developed and output is low and variable. Development of agriculture in this region should aim to adjust the existing agricultural structure which consists only of grain production; by developing forestry and animal husbandry in order to provide a new production system which unites agriculture, forestry and animal husbandry and a coordinated agricultural/ecological system. The region could develop a modern pastoral and oil crops base. To achieve the above, land resources must be allocated as follows: 30% for agriculture; 40% for forestry and 30% for animal husbandry. In the meantime exploitation of rural energy resources and construction of forestry protection belts must be implemented quickly to support the development of the new agricultural structure.

CONCLUSION

In order to develop the mountain resources in this region, but at the same time protect the environment from degradation, importance should be attached to the

following:

- (a) Use of an index system to comprehensively appraise the mountain resource.
- (b) Implementation of soil and water conservation based on small drainage basins.
- (c) Careful attention to the structure and distribution of agriculture in the delicate ecological belt in western Liaoning Province.
- (d) Exploitation of rural energy resources.
- (e) Integrated measures for preventing hazards such as soil erosion and debris flows.
- (f) Integrated measures for protecting mountain environment from pollution.