Chapter 7

Living Terrace Edge — An Effective Method of Slope Utilisation in the Upper Reaches of the Yangtze River

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Abstract

Very similar to Sloping Agricultural Land Technology (SALT) developed in the Philippines, Living Terrace Edge (LTE) is a special erosion control practice in the traditional systems of land use in the sloping areas in eastern China. It is a biological measure for protecting terrace edges from soil erosion and to raise the economic status of farmers. Terraces are part of the landscape in China and the farmers take terracing as an effective way of using their sloping farmlands. Some 27 million hectares of terraces are constructed each year in the country. Terrace edges usually occupy 10-15 per cent of the total land area. If these edges are used appropriately, they provide potential land resources which are valuable for a populous country like China. The application of LTE has been very successful in both an ecological and an economic sense in many provinces of eastern China. This paper reviews the LTE practices in different parts of that region and makes suggestions for the further development of this technique.

Introduction

Upland rain-fed areas often face a serious problem of soil erosion which damages land productivity. This occurs due to heavy rainfall on very steep slopes. Recent developments in agroforestry provide probable ways of putting the development of upland areas on a sustainable footing. A typical example is Sloping Agricultural Land Technology (SALT), developed in the Philippines, which integrates nitrogen-fixing shrubs and trees to minimise soil erosion and maintain soil fertility in crop fields (Tacio 1993). However, upland areas are so diverse in their natural environmental and socioeconomic conditions that no single universally effective model exists.

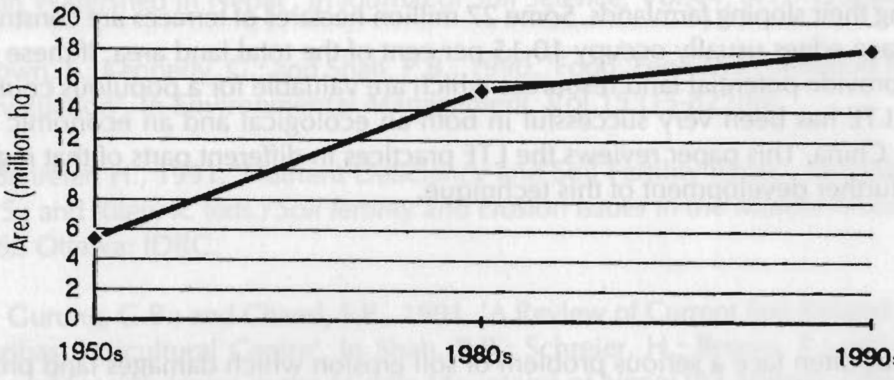
Many current agroforestry systems have evolved from traditional farming practices that have, over the ages, adapted to local circumstances. Living Terrace Edge (LTE) is one such farming practice, used mainly to control soil erosion in the terraced fields of eastern China. The LTE method involves planting small trees, shrubs, and grasses along the edges of terraced fields to protect terrace edges from runoff damage and to use slopeland resources to their full capacity. Species selected for LTE are often special local ones, or other plants, that can prove to be cost effective and raise the income of farmers.

Innovations intended to conserve soils and improve their fertility have not been readily and widely adopted because of the lack of technical adaptation to the farmers' circumstances (Fujisaka et al. 1994). Terracing as an effective way of using slopelands has a long history in China. However, this traditional measure needs updating in many respects, especially the collapse of terrace edges during rainstorms. The LTE method has proved to be effective in allowing surface water to run off a slope without causing much erosion. Another remarkable characteristic of the LTE method lies in its emphasis on direct income from terrace edge plants. (Without various LTE types, farmers can harvest products such as food, fodder, fruit, vegetables, medical herbs, fibre, and perfume materials.)

Problems of Slopeland Utilisation in Eastern China

Population increases and economic developments have placed a great pressure on croplands in China. The problem is especially acute in eastern China, since it is the most populous and fast-growing region in the country. Evidence of this pressure is the accelerating land degradation on sloping lands, which make up some 60 per cent of the total area in the said region. Figure 1 shows the soil erosion trend in the area south of the Yangtze River over the last 40 years. Now the total erosion area in eastern China is 961,898sq.km. This fact is related to the rapid expansion of sloping farmlands in the region in the past four decades. A typical example is that of Jiangxi Province where the total area of sloping farmlands during the 1990s reached 338,106ha, compared to 98,853ha in the 1950s. Over 30 per cent of the sloping farmlands in the province are on steep slopes with a gradient of over 25°. Reclamation of slopelands for cultivation is a major cause of soil erosion. This is evident from the fact that the eroded farmlands account for 76 per cent of the total eroded area in the Pearl River Basin, 47 per cent in the Loess Plateau, and 45 per cent in eastern China as a whole.

Figure 1: Soil Erosion Trend in the Area South of the Yangtze River in the last 40 years



Severe soil erosion has drastically reduced soil productivity and has had serious downstream effects such as sedimentation in river beds, reservoirs, and lakes and flooding in the lowlands. In this connection, farmers in the upland areas are encouraged by the government to control on-farm soil erosion by using various methods with great efficiency. Terracing is a traditional measure and plays a predominant role in on-farm erosion control in China. According to Guo (1992), the total area of sloping farmlands in China is about 33 million ha, of which over 22 per cent are terraced fields. In the Loess Plateau, about 200,000ha of sloping farmlands are converted into terraces each year.

As permanent structures, terraces have a number of advantages over other erosion control measures. For instance, irrigation becomes possible and field operations for farmers are made easy with the reduction of slope gradients. On the Loess Plateau, well-constructed terraces are reported to have reduced 70-95 per cent of the runoff and over 90 per cent of soil loss, increasing yields by up to 100 per cent compared to sloping farmlands without terraces (Yang 1994). Terraces are also effective in moisture retention for they usually have deep soils. The principal alternative to terracing is the contour hedgerow that harnesses erosive forces to form terraces naturally. For this process to be successful, it is essential to have excessive rainfall which, in turn, causes soil erosion and enables natural terracing to take place (Fujisaka et al. 1994). In areas such as the northern parts of the said region, where the application of contour hedgerows is limited because of low rainfall intensity, terracing is even more important.

Yet, terraces have some problems for a number of reasons. These include inadequate drainage, poor design of structures, and low quality construction. An obvious fact in eastern China is that terraces with earth risers constitute a large proportion in many areas due to the shortage of stone or the high unit costs of stone. Earth-riser terraces amount to 70 per cent of the total terraces constructed in recent years in southern Shaanxi Province (Zhu 1994) and 93 per cent in western Henan Province (Zhang et al. 1989). Earth risers are usually prone to failure in rainy seasons, especially in the early years of construction. One example is that from southern Shaanxi Province where 30-40 per cent of the earth risers collapsed the year following construction.

Some masonry terraces easily cave in owing to quick weathering of the stones, for example, the purple sandstone and shale used in Sichuan Province. In this connection, appropriate methods for terrace riser maintenance are vital for sustainable use of terraces.

The Living Terrace Edge – Effective Terrace Protection and Sustainable Slopeland Use

Terraces usually have masonry or earth risers and bunds at the top of the risers which determine the stability of terraced fields. Terrace edges in this paper refer to those parts of the terraces. The land area occupied by terrace edges depends on the original slope gradient and the style of the terrace structure. Terraces with earth risers usually have a large edge area owing to the acute angles of terrace risers. In eastern China, the area of terrace edge varies from five to 20 per cent of the total field area, but more often it is constrained within the range from 10 to 15 per cent.

The use of terrace edges, even for fruit tree plantation, is a long-time tradition among Chinese farmers, especially in southern China. This erosion control technique is gaining widespread acceptance in eastern China. For instance, some 52,200ha of terraces with LTE have been developed in southern Shaanxi Province (Xu et al. 1992) and the Tai'an Prefecture of Shandong Province uses terrace edges on 20 per cent of the land (Li and Xu 1994). Many places have developed successful LTE applications such as Chinese prickly ash in Shaanxi, citron day lily and Indian floating heart in Shandong, Korean lovegrass in Fijian, and mulberry LTE in the provinces of Sichuan, Shaanxi, Shanxi, and Hebei. A summary of plant species involved in LTE application in different provinces in eastern China is presented in Table 1. Most of the plant species involved in LTE are small trees, shrubs, and herbs with high economic values.

Many application projects in eastern China demonstrate the sustainability of the LTE technique. Enumerated below are some of the functions of the technique.

Erosion Control: The preliminary objective for LTE implementation is to enhance the stability of terraces by means of planting small trees, shrubs, and grasses along the edges of terraced fields. Terrace edges are most unstable and erosion prone because runoff is maximised there and the soil surface is exposed to the direct impact of rainfall. Terrace edge plants and their residues can minimise the impact of raindrops as they strike the soil, and they can also be used to form a physical barrier to slow down runoff and filter out sediment. Moreover, the deep and dense roots of terrace edge plants can protect terraces from collapse. According to a report (Xiang 1990) from Shaanxi Province, the bunge prickly ash LTE reduces terrace collapse by 60 per cent during rainstorms. Citron day lily LTE planted five years ago in Shandong Province reduced runoff by 70 per cent and soil loss by 87 per cent (Yang et al. 1993). In Henan Province, the Indian floating heart LTE reduced runoff and erosion by up to 90 per cent and 92 per cent respectively (Zhang et al. 1989).

Other Ecological Benefits: In addition to erosion control and terrace protection, LTE provides other ecological benefits such as improving soil properties, regulating microclimates, and increasing vegetation cover. Tables 2 and 3 present some examples of LTE's effects on temperature, humidity, wind speed, evaporation, soil nutrients, and other physical properties in different places in eastern China.

Economic Benefits: Economic benefits obtained by farmers from an erosion control project determine its sustainability to a large extent. In many respects, LTE implementation can translate into economic benefits for farmers. First, the LTE method saves terrace maintenance cost, which is expensive, especially for terraces with earth risers. Second, the cultivation index is enhanced by the use of terrace edges that would otherwise remain unused. The most significant merit of LTE lies in its emphasis on the direct economic benefit from the terrace edge plant. Many terrace edge plants have output values higher than those of field crops. In Hancheng City of Shaanxi Province, the average output value of terrace edge prickly ash is $1,058 per hectare, accounting for over 10 times that of food crops (Xiang 1990); the output value of terrace edge mulberry was reported to be $882 per hectare in Hebei Province in the early 1980s, amounting to three times that of peanuts and two times that of cotton (Liang 1990); the terrace edge rose in Shanxi Province has an output value as high as $12,970 per hectare (Li 1991).

Table 1: Plant Species Used for Living Terrace Edge Applications in Eastern China

Species Name	Common Name	Usage	Reported Area
Tree species			
Toona sinensis	Chinese toona	Vegetable	Shaanxi
Quercus hopeiensis	oak	Fibre	Shaanxi
Paulownia elongata	paulownia	Wood	Shaanxi
Trachycarpus fortunei	windmill palm	Fibre, oil	Shaanxi
Ziziphus jujuba	Chinese date	Fruit	Shaanxi, Shandong
Diospyros kaki	persimmon	Fruit	Shandong, Shaaxi
Citrus	citrus	Fruit	Shaanxi
Juglans cathayensis	Chinese walnut	Fruit	Hebei
Eriobotrya japonica	loquat	Fruit	Sichuan
Castanea mollissima	hairy chestnut	Fruit, food	Shaanxi
Eucommia ulmoides	eucommia	Medicine	Shaanxi
Shrub species			
Camellia sinensis	tea	Tea	Shanxi, Guizhou, Fujian
Hippophae rhamnoides	seabuckthorn	Fruit	Shaanxi
Ribes burejense	bureja gooseberry	Fruit	Jiangsu, Shaanxi
Morus alba	white mulberry	Fibre	Shanxi, Sichuan, Hebei, Shaanxi
Coriaria sinica	Chinese coriaria	Fibre	Shaanxi
Rhus chinensis	Chinese sumac	Medicine	Shaanxi
Nymphoides indica	Indian floating heart	Medicine	Shandong, Shanxi, Shaanxi
Rosa rugosa	rugose rose	Perfume	Jiangsu, Shaanxi
Jasminmum nudiflorum	winter jasmine	Medicine	Shaanxi
Gardenia jasminoides	cape jasmine	Medicine	Shaanxi
Ziziphus jujuba	spine data	Fruit	Shanxi, Shaanxi
Amorpha fruticosa	shrubby amorpha	Fibre, green manure	Hebei, Shandong, Shanxi
Caragana korshinskii	korshinsk peashrub	Fibre	Shaanxi
Tamarix ramosissima	branchy tamarisk	Fibre	Shanxi, Shaanxi
Fraxinus bungeana	ash	Fibre	Jiangsu, Shaanxi
Lespedeza dahurica	shrub lespedeza	Food	Heilongjiang
Salix integra		Fibre	Jiangsu, Shaanxi
Salix nigra		Fibre	Shaanxi
Salix cheilophila	sand willow	Fibre	Shaanxi
Coronilla emerus	coronilla	Green manure	Shaanxi
Zanthoxyllum bungeanum	bunge prickly ash	Flavouring	Shandong, Jiangsu, Shaanxi
Herb and grass			
Hemerocallis citrina	citron day lily	Vegetable	Shandong, Shaanxi, Shanxi
Dendranthema morifolium	chrysanthemum	Medicine	Shaanxi
Eulaliopsis binata	common eulaliopsis	Fibre	Shaanxi
Medicago sativa	alfalfa	Fodder	Shaanxi
Miscanthus sinensis	miscanthus	Fibre	Shaanxi
Eragrostis ferruginea	korean lovegrass	Fodder	Fujian
Glycine max	soybean	Food	Heilongjiang
Vicia faba	broadbean	Food, green manure	Hubei
Vigna sinensis	common cowpea	Green manure	Hubei
Vine species			
Vitis vinifera	grape	Fruit	Shaanxi

Table 2: Changes in Soil Properties (0 - 20cm) after Implementing LTE in Some Areas of East China

LTE type	Location	Physical properties		Chemical properties		
		Bulk density	Water content	Organic matter	N	P_2O_5
Indian floatingheart	Songxian, Henan	-16%	+32%	+43.1%	+42.5%	NA
Rugose rose	Linfen, Shanxi	-7%	NA	+22%	+32%	+2%

Note: based on Zhang et al. (1989) and Li (1991)

Table 3: Changes in Microclimatic Conditions (Summers) after Implementing LTE in Some Areas of East China

LITE type	Location	Soil surface temperature	Air temperature	Relative humidity	Evaporation	Wind speed
Prickly ash	Hancheng, Shaanxi	-0.57°C	-1.11°C	+4%	-23.7%	-30.25%
Mulberry	Qian'an, Hebei	-0.7 - 1.56°C	NA	+7%	NA	NA
Citron day lily	Tai'an, Shandong	NA	-1°C	+18%	-20%	-30%

Note: based on Xiang (1990), Liang (1990) and Li (1994)

Living terrace edges may, however, have negative effects on adjacent crops in terraced fields owing to their competition with field crops for light, water, and soil nutrients. According to Zhang's (1989) observation in Henan Province, shrubby *amorpha* has a strong impact on the soil water availability of adjacent crops and can affect the moisture level of the soil two metres away from terrace edges. Some yield reduction has also been observed in the rows nearest to terrace edge plants such as *paulownia* and korshinsk peashrub (Zhang 1986). However, yield reduction of field crops may not reduce the overall output value of the land-use system if the terrace plants are taken into account. To minimise the negative effects of terrace edge plants on field crops, appropriate species should be selected and the LTE technique should be well designed.

Towards Sound Technical Design for the Living Terrace Edge

It can be seen from the last section that the LTE is very successful in both ecological and economic terms in many places. However, poorly designed LTE projects are bound to fail due to the edge effects of LTE plants, or because of other reasons. Thus, it is necessary to formulate some principles for LTE design in order to make it a sustainable method of slopeland use. Several aspects of LTE design need to be considered.

LTE — A Component of the Land-use System

Living terrace edge, as well as being an erosion control measure is also a land-use type, considering the fact that both field crops and terrace edge plants make up an intercropping scheme. Ordinarily, when an intercropping practice fails it is because of the negative effects of minor components on the major ones. In this connection, the structures of this intercropping system, such as species' structure, production structure, and land-use structure, would be designed as part of overall land-use planning. In view of the economic benefits, the major products of the intercropping system may come from field crops or terrace edge plants. If the latter is determined to be the major component of the farming system, the edge effects of living terrace edges become no more significant. A well-coordinated interrelationship between field crops and terrace edge plants will ensure sustainability of the erosion-control function of living terrace edges.

Choice of Species

Factors affecting species' selection for terrace edge plants include environmental adaptability, erosion control capability, economic value, and edge effects. Plants with higher environmental adaptability are often chosen because of their easy establishment and management. Shrubs and perennial herbs with deep root systems and coppicing abilities are the best choice for erosion control, because it is easy to establish a vegetative barrier to slow down runoff and erosion from the ground surface with these plants. To minimise the edge effects of LTE, plants with a laterally spreading root system and a large canopy should be avoided at the time of selection. The income-generating capacity of the terrace edge plants' products determines the farmers' attitude to application of the LTE method. Experiences from eastern China show that special local plants often have higher income benefits and ensure LTE project success.

Planting Position

LTE can be established on both terrace risers and on the top earth bunds for earth-riser terraces. For masonry terraces, however, terrace edge plants can only be planted at the extreme edge of the earth terrace and choice of species is limited to small shrubs and perennial herbs which have little edge effect. An earth riser often has a slope so as to provide a larger space for LTE development. For earth risers with a relatively large height or small slope gradient, plantation of small trees and large shrubs is possible, but, at the top of terrace risers, plants must first be grass and shrubs with little edge effect. The trend of a terrace also affects the establishment of LTE. A north-south extended LTE usually has a smaller shading effect on field crops than an east-west one. Thus, the former has a wider choice of species than the latter.

Conclusion

Contour hedgerows have shown a number of advantages over other methods to deal with soil erosion in the humid tropics. In those mountain areas without the heavy rainfall intensity of the humid tropics, farmers are not easily persuaded to accept the method because natural terracing lasts longer. This is especially the case in China where large areas of terrace structures exist and farmers prefer artificial terracing to control soil and water erosion. Thus, the living terrace edge is an effectual way to solve the problem since it harnesses both the structures and vegetative techniques. Moreover, slopelands can be used to a greater extent with the implementation of living terrace edges.

Although some pilot projects in LTE application have been successful in eastern China, there are still some information gaps that need to be bridged. A common problem encountered in LTE applications is the edge effects of terrace edge plants. The performance of these plants in intercropping systems, especially their root systems, requires detailed trials since little knowledge is available. The method of economic appraisal for LTE implementation also deserves further research. Both the economic and ecological benefits of the vegetative method should be assessed in a quantitative way to assure the sustainability, as well as the productivity, of the land-use system.

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