EFFECTIVE CONSERVATION PRACTICES FOR THE CULTIVATION OF SLOPELANDS

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ABSTRACT

Hillside ditches, bench terraces, grass covers, grass strips, and surface mulches are the most common conservation practices used in Taiwan, mainly on gentle slopes. A field experiment site was set up in an orchard on a 60% slope, to test their effectiveness in conserving soil and water resources. Field measurements indicated that these practices were equally effective on steep slopes. However, grass strips with a residue mulch laid between the strips are probably the most cost-effective and functional conservation measure on slopeland orchards in high-rainfall areas.

BACKGROUND

The island of Taiwan is 142 km broad at its widest point, and 377 km long. The Central Mountain Range runs along the entire length of the island, surrounded by a narrow zone of foothills. From the foothills, the terrain gradually falls to tableland 100 - 500 m in elevation.

In this Bulletin, hilly land refers to slopelands with an altitude of 100 to 1000 m. Hills with an altitude of less than 100 but slopes of more than 5% are also considered to be slopeland. Such terrain comprises 27% of the island's land area.

Furthermore, the overall rise in the standard of living has resulted in major changes in consumption patterns. Rice consumption, for example, fell sharply by 18% from 1990 to 1995, while that of fish, meat, vegetables, and fruit has increased. In recent decades, agricultural imports have increased while agricultural exports have fallen. According to government surveys, 60% of Taiwan's farm households earn only US$7200 annually, while 70% of farms are less than one hectare in size. With the fall in rice consumption, farmers have been forced to switch to high-profit cash crops such as tea, high-altitude vegetables and fruits, and betelnut. In response to economic pressure, much of Taiwan's agriculture has migrated upward into high slopeland areas. The results have been deforestation and land disturbance. This in turn has increased the possibility of soil erosion, especially in view of Taiwan's humid climate.

The climate in Taiwan is subtropical in the north and tropical in the south. Rainfall is abundant, yet concentrated into the summer and winter monsoons. The average annual rainfall approaches 2430 mm, while about 78% of the annual precipitation falls in the summer, from May to October, which is also the typhoon season.

There have been 348 typhoons in Taiwan over the past one hundred years, an average of 3 - 4 typhoons each year. Typhoons not only bring gusty winds, but also carry huge quantities of rain. One major typhoon, Herb, hit Taiwan on July 31, 1996 and poured 1100 mm of precipitation onto mountain areas in a single day. This heavy rainfall caused landslides and flooding, which resulted in 27 deaths and extensive damage. Taiwan's steep terrain, brittle rocks, unstable stratum and concentrated rainfall make it highly vulnerable to erosion.

COMMON CONSERVATION PRACTICES IN TAIWAN

For better management of land resources, the government established its first soil conservation demonstration project in 1952. Since then, a number

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of soil conservation practices have been developed to suit local needs. These practices include hillside ditches, bench terraces, grass barriers, cover crops and mulching (Liao 1980, Lee 1984).

Hillside Ditches

Hillside ditches consist of a series of shallow ditches built along the contour lines at appropriate intervals (Fig. 1). Hillside ditches not only break long slopes into shorter segments to intercept surface runoff, but also serve as farm paths to facilitate farm operations and transportation. They have been shown to be suitable on slopes with a gradient of less than 40%.

Bench Terraces

Bench terraces consist of a series of level or nearly level platforms built along the contour lines at suitable intervals (Fig. 2). They are suitable for slopeland farms with a considerable depth of soil, and for farms which are being intensively cultivated. Because a large amount of cutting and filling is required per unit area, bench terraces may not be the optimum practice on easily eroded soils.

Grass Barriers

Grass barriers consist of grass planted in strips along the contour lines. The strips are spaced at suitable intervals to retard runoff velocity and to retain eroded soil. Eroded soil retained behind the grass strips will eventually form natural bench terraces.

Cover Crops and Mulches

Cover crops and mulches basically apply live vegetation or vegetation residues, respectively, to the soil surface so that there is no erosion from exposed soil. Both practices also help suppress the growth of weeds, provide additional organic matter, and improve the physical and chemical properties of the soil.

Stone Walls

Stone walls are another conservation practice sometimes used in Taiwan. Farmers use rocks and stones lying on the slope, as well as those retrieved during cultivation, to build low stone walls. Stone walls not only help reduce soil and water losses, but also help minimize the slope gradient to facilitate cultivation and mechanized farming operations.

Discussion

According to the 1995 annual survey carried out by the Soil and Water Conservation Bureau, hillside ditches are the most common conservation practice used on slopeland in Taiwan, followed by bench terraces, grass cover, and stone walls, in that order. Hillside ditches were used on a total of 985 ha of farmland, bench terraces on 90 ha, grass cover

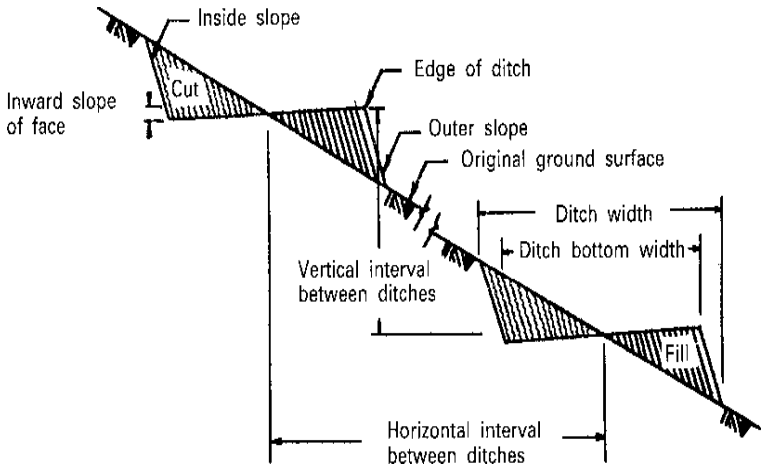

Fig. 1. Sketch of hillside ditch

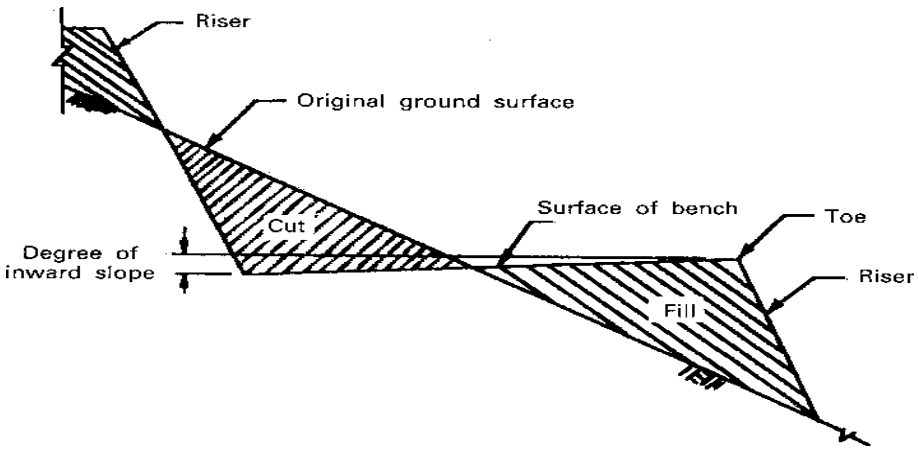

Fig. 2. Sketch of bench terrace

on 67 ha and stone walls on 4 ha (Statistical Yearbook of Taiwan Province 1996).

The migration of agriculture from lowland to highland may partially meet new market demands. However, the loss of fertile topsoil, and the off-site environmental impact caused by soil erosion, have become major problems. Even though Taiwan has a great deal of experience in soil conservation, this were mainly agriculture on gentle slopes at low altitudes.

ASSESSMENT OF SLOPELAND CONSERVATION MEASURES

Site Description and Experiment Setup

In order to verify the effectiveness of conservation practices on sloping lands, an outdoor experimental site was installed in the campus of National Pingtung University of Science and Technology in Taiwan. The entire site occupied 0.2 ha, with an average gradient of 60% (30.96°). The soil was classified as a sandy clay loam, according to United States Department of Agriculture (USDA) standards. The experimental site had formerly been used for growing mango. All mango trees and ground vegetation were removed at the beginning of site preparation. Some grading was done to the slope to achieve uniformity.

Seven runoff plots were installed on the experiment site. Each plot had a slope length of 22 m, and a width of 4 m. Brick walls were used to partition the plots, and a set of stilling basins was constructed at the downslope end of each plot to collect surface runoff and eroded soil. Several conservation practices were selected for this study. They included Bahia grass (*Paspalum notatum Flugge*) as ground cover in a litchi orchard (Treatment A); bare check plot (Treatment B); Bahia grass cover alone (Treatment C); Bahia grass cover plus a hillside ditch in a litchi orchard (Treatment D); Clear-cut Litchi orchard (Treatment E); Bahia grass strips plus a grass residue mulch between strips in litchi orchard (Treatment F), and betelnut plantation without ground vegetation (G).

Bahia grass is the grass most often used for soil conservation in Taiwan. It should be mown two or three times each year to facilitate farm operations. Farmers are encouraged to recycle the Bahia grass residues by applying them to areas of bare soil. The source of the Bahia grass residues applied in Treatment F came from the grass strips. Therefore, the amount of Bahia grass residues used as a mulch depended on the amount of biomass that each grass strip could provide.

At the end of each rainy season, exposed soil was plowed to a depth of 30 cm to break up possible surface crusts, so that the sealing effect from the previous rainy season would not carry over to the next. Air-dried soil stored in a warehouse was added to the replowed plots to compensate for lost soil. For those plots receiving fresh soil, manual grading was applied to achieve a uniform slope.

Table 1. Summary of annual soil loss and surface runoff

Year	Effective Precipitation (mm)	Treatment A	B	C	D	E	F	G
		Total soil loss (kg/m^2)						
1992	1360.4	0.00	28.80	0.00	0.00	22.11	0.08	20.46
1993	765.0	0.00	25.89	0.00	0.00	24.89	0.00	28.82
1994	2413.0	0.00	44.17	0.01	0.01	25.88	0.00	22.92
1995	1260.0	0.01	36.65	0.01	0.01	19.74	0.00	15.95
Average		0.00	36.52	0.01	0.01	23.53	0.02	21.61
		Total surface runoff (m^3/m^2)						
1992	1360.4	0.000	0.072	0.000	0.004	0.063	0.004	0.074
1993	765.0	0.000	0.125	0.000	0.002	0.059	0.000	0.189
1994	2413.0	0.002	0.448	0.004	0.009	0.227	0.002	0.513
1995	1260.0	0.003	0.166	0.007	0.007	0.090	0.002	0.126
Average		0.002	0.256	0.003	0.007	0.137	0.002	0.283

Remarks: Treatment A - Litchi + Bahia grass cover
Treatment B - Bare check plot
Treatment C - Bahia grass cover only
Treatment D - Litchi + Hillside ditch + Bahia grass cover
Treatment E - Clean-cut litchi orchard
Treatment F - Litchi + Bahia grass strips + Grass residue mulch
Treatment G - Betel nut plantation without ground vegetation

Measurements

Measurements include daily precipitation, surface runoff and soil loss. A 0.5-mm standard tipping-bucket rain gauge connected to a data logger was used to record daily precipitation at 15-minute intervals. Two stilling tanks were constructed at the downstream end of each plot to store the surface runoff and sediment. The volume of surface runoff and soil loss was measured each time erosion occurred, usually after a storm or heavy rainfall.

DISCUSSION

The annual soil loss and surface runoff from four consecutive years are summarized in Table 1. The term 'effective precipitation' in Table 1 refers to the total amount of daily precipitation when soil erosion was observed at the site. The average soil loss was calculated by first weighing soil sediments upon the effective precipitation, then adding together all measurements for soil loss taken the same year, and finally, dividing the results by the total effective precipitation. The average surface runoff was calculated in the same manner.

Field observations indicated that Treatments A (Litchi + Bahia grass cover), C (Bahia grass cover), and F (Litchi + Bahia grass strips + Grass residue mulch) produced the least surface runoff. The reasons were mainly the presence of grass roots that served as additional paths into which runoff could infiltrate, and the absorption capability of grass and grass residues. Laboratory experiments have shown that air-dried grass residues can absorb as much as 4.8 times their own weight of water. This trapped water will be gradually released over a period of several days (Wu *et al.* 1995).

Treatment D (Litchi + hillside ditch + bahia grass cover) was equally effective in controlling soil loss. The amount of surface runoff produced from treatment D was slightly higher than those from treatments A, C, and F, but this was mainly because of the experiment design, since there was a PVC pipe installed flush with the bottom of the hillside ditch to convey surface runoff from the upper slope to the stilling tank. In reality, hillside ditches are often linked to drainage waterways to drain excess surface runoff safely away.

Even though hillside ditches were shown to be effective in conserving soil and surface runoff,

they do have disadvantages. Ditches need to be excavated, and the fill disposed of. This not only adds to the cost, but also disturbs the topsoil. Similarly, bench terraces are built by cutting and filling, which has the same effect. Neither hillside ditches nor bench terraces will achieve their full potential in erosion control until the disturbed soil becomes stabilized.

The soil loss from treatment G (betelnut without ground vegetation) was slightly less than that from treatment E (clear-cut litchi). Conversely, surface runoff was greater from the betelnut plot. The reasons for this are related to crop height and the characteristics of the crop canopy. A betelnut tree can reach a height of 4 m, whereas litchi trees at the same age are only 2 m high (they are trimmed twice a year). Hence, the average distance which intercepted raindrops fall from the canopy is less in the case of litchi. In addition, the canopy of betelnut palms is smaller than that of litchi. Smaller drop size, shorter fall height, and larger canopy cover in the litchi plot reduced the impact energy. In the betelnut plots, because of the greater raindrop impact, surface crusting was observed. This protected the soil to some extent from erosion, but also made it less permeable.

The soil loss from treatment B (bare plot) was the highest of all treatments, as could be expected. Average soil loss each year from a bare plot with a slope of 60% may reach 36.5 kg/m^2 (Table 1). If we ignore the factors affecting sediment delivery, average annual soil loss will reach 365 mt/ha, which is equivalent to the loss of 2.4 cm of topsoil.

From the viewpoint of cost effectiveness, the combination of grass strips and a residue mulch is probably the best choice for conserving soil and water resources in steeply sloping orchards. The grass strip not only protects the soil from erosion, but also serves as a barrier to trap eroded sediments. A residue mulch applied between the grass strips has multiple functions. These include protecting soil from erosion, conserving surface runoff for use by the crop, and adding to soil organic matter content. There is little competition for water and nutrients between the grass strips and the crop.

CONCLUSION

Soil erosion is a natural process that can take place at any time and at any site. It may be noticeable even if natural weathering is the only erosive agent. Human activity, on the other hand, including both agriculture and non-agriculture, may accelerate erosion processes. As land is opened to any form of development, disturbed soil is immediately subject to soil erosion unless it is well protected from the erosion agents.

Grass covers, grass strips, surface mulch and hillside ditches were found to be effective, not only on gentle slopes but also on steep ones. These conservation measures can greatly reduce soil losses and conserve surface runoff. If no conservation is practiced, the average annual soil loss from a 60% bare slope may reach 36.5 kg/m^2. A combination of grass strips and residue mulch between strips is the most cost-effective and functional practice for steeply sloping orchards.

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