SOIL AND WATER LOSSES IN REFORESTATION INTERCROPPED WITH VETIVER STRIPS AT THE PING, WANG, YOM AND NAN SUB-RIVER BASINS OF NORTHERN THAILAND

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Abstract

Determination of soil and water losses in reforestation intercropped with vetiver strips was conducted in four upper watershed research station (WRS) areas which lie in the Ping (Mae Taeng WRS), Wang (Wang WRS), Yom (Yom WRS) and Nan (Khun Sa Than WRS) sub-river basins in Northern Thailand during 1994-98. The investigation was carried out on three replications of 4 x 20 m, 4 x 40 m and 4 x 60 m runoff plots, which were constructed on 20, 30 and 40-percent sloping areas of natural forest, furrow, reforestation and reforestation intercropped with strips of vetiver. It was found that, for the 20-percent sloping area at the Mae Taeng WRS, the natural forest produced minimum runoff and soil loss with values of 5.5 mm and 3.429 t/ha/yr. The reforestation intercropped with the grass strip yielded minimum water and sediment loss when compared to the plantation and furrow plots with the values of 8.0, 15.2 and 12.2 mm and 2.501, 7.325 and 3.962 t/ha/yr, respectively. Similarly, in the Yom watershed, the reforestation plot intercropped with grass strips generated runoff and soil loss with the values of 54.6, 57.8 and 51.8 mm and 0.388, 0.553 and 0.442 t/ha/yr, respectively. Likewise, on the other slopes, the results showed minimum loss of soil and water in the plots intercropped with grass strips due to the dense grass hedges, which decreased surface flow velocity. However, the natural forest yielded the minimum runoff and soil loss on average during the study period.

Introduction

Soil erosion is a natural process that can be accelerated by human activity. It is a source of social and economic problems and an essential factor in assessing ecosystem health and function. In Thailand, many researchers have studied water erosion in various regions. A study in Northeast Thailand showed that the annual mean soil and water losses in forest plantation, cash crop, agroforestry and grassland were 0.2, 9.6, 5.9, and 0.4 t/ha, and 40, 329, 293, and 55 mm per year, respectively (Vannaprasert and Thongmee 1993). Steep terracing with reforestation on rugged terrain at Doi Ang Khang, Chiang Mai, Northern Thailand, indicated a reduction of 16-600 times of soil loss and 6-15 times of surface runoff, respectively, after three years of planting compared to bare land (Tangtham et al. 1988). When the plantation was seven years old, soil loss was observed at less than 0.2 t/ha/yr, with water loss of about 40 mm/year (Tangtham 1995). Conservation measures such as hillside ditches, intermittent terraces, contour bunds and bench terraces reduced soil loss from 31 t/ha in the cash crop planting plot (30-percent slope) to 12, 10, 8, and 5 t/ha, respectively. The average annual water loss from these conservation-measured plots was about 90, 87, 82 and 79 mm/year respectively, which was a little less than that of a bare area (91 mm/year) (Tangtham and Korporn 1997). Paramee (1999) reported that burned dry dipterocarp forest yielded very high soil loss of 0.719 t/ha/yr, whereas jackfruit, cashew and mango produced less sediment of 0.144, 0.103, 0.080, and 0.039 t/ha/yr than the burned area did. The ground surface cover and root system of weeds are primarily responsible for reducing soil and water losses and for the different values in land use.

As a result, soil and water conservation measures deserve future management and sustainable use. Vetiver grass is an effective vegetative erosion control tool widely used in this country. It has been promoted to reduce surface runoff flow velocity in sloping areas. The grass has also been provided for soil and water conservation in various land uses in the country. Vetiver grass hedges act as filters to slow and broaden the water flow area, resulting in ponding which increases the setting time for suspended material to be deposited (Jerry and Doral 1999). The main objectives of this study were to investigate the potential of vetiver hedges on erosion control and to quantitatively study the significant difference of runoff and soil loss among plantations intercropped with vetiver strips.

Study Site Description

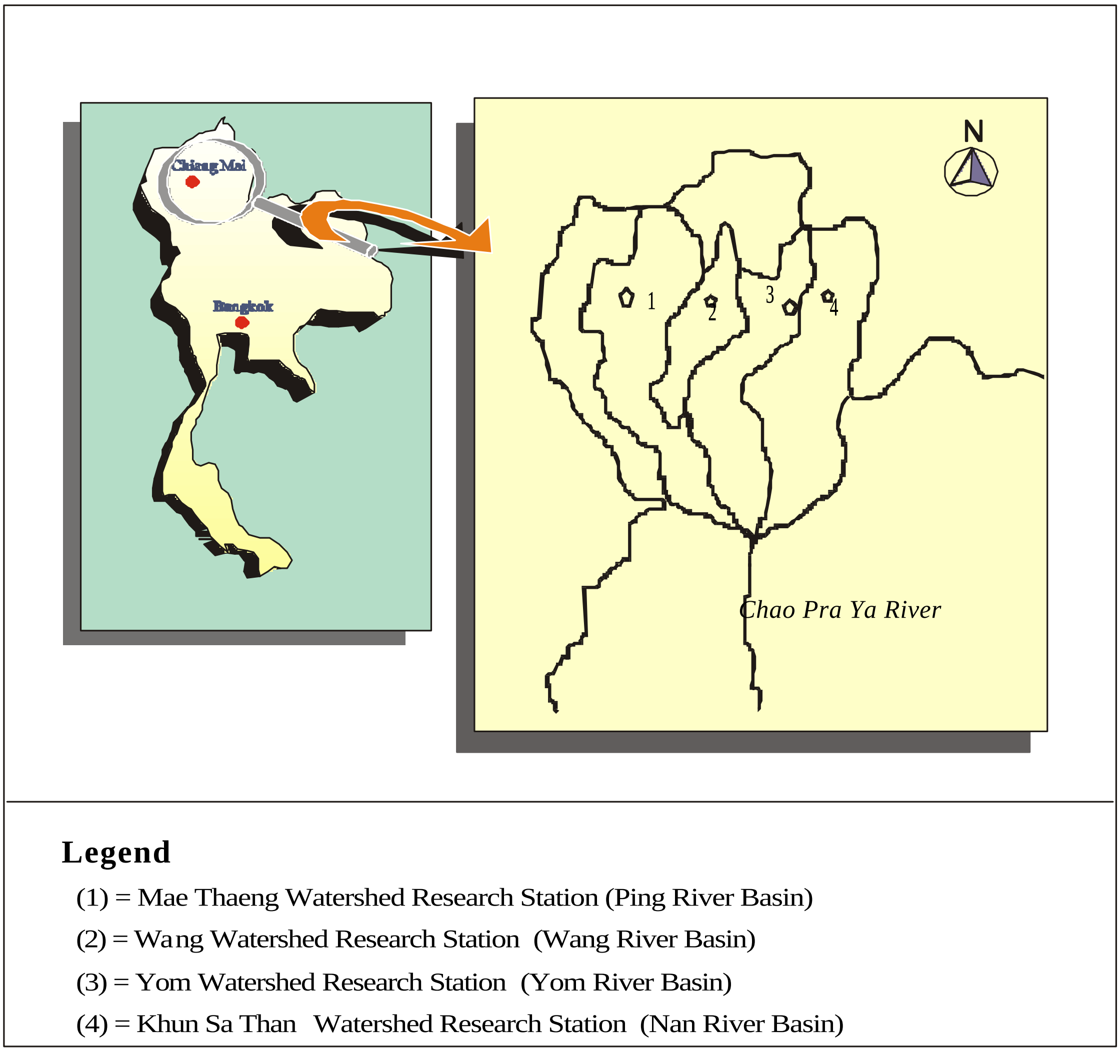

Figure 1 Location of experimental plots in Watershed Research Station.

Four upper watershed research stations (WRS) were established in the river basins of the Ping (Mae Taeng WRS), Wang (Wang WRS), Yom (Yom WRS) and Nan (Khun Sa Than WRS), which cover much of Northern Thailand (Fig. 1). The topography of the basins is dominated by mountains with an elevation of 350 m to 1 600 m and over 50% of the entire watershed areas has a high slope complex. More than three quarters of the basins are covered by natural forest and reforested areas, and the remaining 25% of land is used for human settlement and water storage and as urban area or agricultural land. The climate of the area is influenced by the annual monsoon. There are three distinct seasons: the rainy, cold and hot seasons. Sometimes the cold and hot seasons are collectively known as the dry period. The rainy season usually lasts from the middle of May until the end of October; the cold season from November until the beginning of February; and the hot season from February until the beginning of May when the rains normally begin. The precipitation data on the area are summarized in Table 1.

Table 1. Precipitation in the watershed research stations during 1994-98 (unit: mm)

Month	Mae Tang	Wang	Yom	Khun Sa Than
Jan	0.0	1.9	0.0	
Feb	0.0	10.1	1.5	
Mar	22.1	10.2	2.9	
Apr	44.56	90.8	16.5	
May	110.4	221.1	166.4	
Jun	123.3	168.6	153.8	
Jul	221.7	225.1	192.5	
Aug	211.1	287.7	268.4	
Sep	189.2	241.5	253.6	
Oct	124.1	172.3	98.5	
Nov	7.4	78.1	1.9	
Dec	0.0	15.7	0.0	
Total	1053.8	1562.2	1,156.0	1615.6

Material and Methods

Data Collection

The technique of the randomized block design was used for plot placing in various land uses. The 4 x 20, 4 x 40 and 4 x 60 m rectangular experimental plots with three replications were constructed on each predominantly 20, 30 and 40-percent uniform slope of natural forest, furrow, reforestation, and reforestation intercropped with strips of vetiver. The grass was strip-planted perpendicular to the slope with 20 m width. Plots were bounded by cement blocks sealed with concrete edges, 25 cm high, forced 10 cm into the soil, leaving about 15 cm above ground. At the downhill end of each plot the borders angled to a V-shape directing runoff to a 7.5 cm tube at the apex. Runoff ran down the tube into the collecting tank where samples were obtained.

The instruments were installed and measured the storm events as follows:

1. Rainfall amount was measured with both standard and automatic rain gauge adjacent to the plots, and analysed as erosive agent.
2. The depth of runoff was measured by a simple gauge for the depth of water in the tank. The runoff volume measurement was taken within 24 hours after the event and the collected data were represented with a daily value. The event was calculated in depth of flow based on runoff volume and area of representative plots.
3. Sediment samples were collected from the tanks. After measuring the height of surface runoff in the tank, the runoff mixed with sediment fed in the tank was stirred until the soil particles were thoroughly mixed with the water. Samples of one litre of water each were collected from the stirred water using plastic bottles. A flocculating agent was added to the mixture of water and sediment collected in the bottles. After most of the soil particles settled at the bottom of the bottles, clear water was drained out until almost none was left. A filter paper was used to filter the soil particles from the water samples. The filtered sediment or soil particles were oven-dried at 105^oC over 24 hours and weighed. The amount of sediment present in the collected surface runoff was determined. The sample weight of sediment multiplied by the total volume of the surface runoff was assumed to be the total weight of soil loss from the plot for each event.

Data Analysis

The analysis proceeded as follows:

1. Runoff volume from each treatment plot was calculated by the method described above and the results were compared between the treatments.
2. Soil loss amount for each event was calculated in mass per unit area per unit time by the oven-dried sediment sample and weight. The total sediment from the plots for the storm events was obtained for representative area interpretation.
3. The arithmetic mean technique was used to estimate the mean value of soil and water loss between the different dimensions of the experimental plots on each slope.
4. The method of least significant difference was used to determine statistical significant differences among runoff and soil loss measured from each treatment plot.

Results and Discussion

Precipitation

During the study period, annual precipitation in the watersheds ranged from 1 012.2 to 1 168.0 mm in Mae Tang WRS, and 1 323.7 to 1 925.9 mm, 995.0 to 1 214.6 mm and 1 311.7 to 2 188.0 mm in Wang WRS, Yom WRS and Khun Sa Than WRS, respectively.

Surface Runoff

The annual runoff and runoff coefficients generated from the various treatments are summarized in Table 2. The runoff ranged from 3.4 to 17.2 mm in Mae Tang WRS and 5.6 to 15.7 mm, 21.3 to 57.8 mm and 4.5 to 30.9 mm in Wang WRS, Yom WRS and Khun Sa Than WRS, respectively. The runoff coefficients ranged from 0.3 to 1.6 % in Mae Tang WRS and 0.4 to 1.0 mm, 1.8 to 5.0 mm and 0.3 to 1.5 mm in Wang WRS, Yom WRS and Khun Sa Than WRS, respectively. Variation of the surface runoff was not constant throughout the five-year period, depending upon the annual rainfall and rainfall intensity distribution.

The runoff volume produced from the undisturbed forest was lower than the volume generated from the other land uses with a ratio of 1:1.5-3 (5.5:8.0-15.2 mm). The greater runoff was obtained due to the higher slope steepness of the area. These results showed that canopy and ground surface cover in the area were also quite effective in reducing runoff. Meanwhile, the low runoff volume from the reforestation intercropped with vetiver strips can also be attributed to increased surface retention and infiltration caused by decreased surface flow velocity.

Statistical analysis of the mean annual runoff from the treatments was conducted using the ANOVA single factor. The significant differences in water losses from the experimental plots are summarized in Table 3. The annual runoff generated from the vetiver strips under reforestation plots with 20-% slope was a significant difference compared to other land uses, whereas the annual runoff from the natural forest, furrow and reforestation plots with 20-% slope had non-significant differences.

There was significantly less runoff with the vetiver strips under reforestation with 20-% slope than with the teak plantation in Yom WRS. On the other hand, there was a non-significant difference between the vetiver strips under the teak plantation and the natural forest and furrow areas. Although the soil surface in the teak plot was undisturbed during the study period, raring on the ground surface cover with secondary growths was directly attacked by raindrops during a storm. These results generally indicated that first, annual runoff volumes decreased, presumably because of the establishment of vetiver hedges on the plots which reduced surface flow velocity, and second, the decrease in runoff flow velocity on the treatment can be attributed to an increase in the surface retention and infiltration rate.

Magnitude of Soil Loss

Annual soil losses are summarized in Table 4. Except for the natural forest, the reforestation intercropped with vetiver grass yielded the lowest soil loss in average values of 2.512, 0.041, 0.388 and

0.061 t/ha/yr in Mae Taeng, Wang, Yom and Khun Sa Than WRS, respectively. Runoff erosivity was reduced under forest plantation intercropped with the vetiver strips.

Fig. 2 illustrates the potential of soil erosion control of vetiver grass hedges in the study areas. Forest plantations intercropped with vetiver strips showed minimizing of soil and water losses. The vetiver grass hedges helped reduce sediment loss by slowing down the surface runoff flow velocity. Runoff erosivity was efficiently weakened by dense vegetative hedges. Even though the lowest sediment loss occurred in the natural forest, the vetiver hedges also showed their efficiency in soil erosion control as per the results in this study. Soil water retention and infiltration rates were higher due to the establishment of macro pores in the upper soil layer thanks to an improvement in the ground surface cover. The grass hedges also contributed to the decrease in runoff flow after the strips were planted in the reforestation areas. The slowdown of surface flow velocity influenced dramatically the deposition of soil particles during transportation.

The statistically significant differences in annual soil loss produced from the treatments are summarized in Table 5. The differences in soil loss produced from the reforestation intercropped with vetiver grass were statistically significant; they were lower than in the other plots except the natural forest areas. There were non-significant differences between the natural forest, furrows and reforestation areas.

Table 2. Annual runoff and runoff coefficients from various land uses at three WRS during 1994-98

(1) Mae Taeng WRS

	Dry evergreen forest		Furrow		Teak		Teak + vetiver	
Slope	Ro	Rc	Ro	Rc	Ro	Rc	Ro	Rc
20%	5.5	0.5	12.2	1.2	15.2	1.4	8.0	0.8
30%	3.6	0.3	11.6	1.1	13.4	1.3	8.2	0.8
40%	3.4	0.3	11.6	1.1	17.2	1.6	8.5	0.8

(2) Wang WRS

	Hill evergreen forest		Furrow		*Pinus kesiya*		*P. kesiya* + vetiver	
Slope	Ro	Rc	Ro	Rc	Ro	Rc	Ro	Rc
20%	6.1	0.4	12.3	0.8	10.5	0.7	8.9	0.6
30%	5.6	0.4	8.6	0.6	9.7	0.6	8.2	0.5
40%	7.8	0.5	15.7	1.0	13.6	0.9	10	0.6

(3) Yom WRS

	Hill evergreen forest		Furrow		*Pinus kesiya*		*P. kesiya* + vetiver	
Slope	Ro	Rc	Ro	Rc	Ro	Rc	Ro	Rc
20%	7.4	0.5	30.9	1.9	12.9	0.8	12.1	0.7
30%	4.5	0.3	10.1	0.6	12.4	0.8	12.6	0.8
40%	4.6	0.3	19.8	1.2	24.1	1.5	15.8	1.0

NB: Ro = runoff (mm), Rc = runoff coefficient (%)

Table 3. Significant differences in annual runoff from various land uses at the four WRS

(1) Mae Taeng WRS

	Dry evergreen forest	Furrow	Teak	Teak + vetiver
Dry evergreen forest	-			
Furrow	ns	-		
Teak	ns	ns	-	
Teak + vetiver	*	ns	ns	-

(2) *Wang WRS*

	Hill evergreen forest	Furrow	*Pinus kesiya*	*P. kesiya* + vetiver
Hill evergreen forest	-			
Furrow	ns	-		
Pinus kesiya	ns	ns	-	

Pinus kesiya + vetiver	ns	*	ns	-
(3) *Yom WRS*				
	Mixed deciduous forest	Furrow	Teak	Teak + vetiver
Mixed deciduous forest	-			
Furrow	ns	-		
Teak	ns	ns	-	
Teak + vetiver	ns	ns	*	-
(4) *Khun Sa Than WRS*				
	Hill evergreen forest	Furrow	*Pinus kesiya*	*P. kesiya* + vetiver
Hill evergreen forest	-			
Furrow	ns	-		
Pinus kesiya	ns	ns	-	
Pinus kesiya + vetiver	ns	ns	*	-

*NB: * = confident interval 95%, ns = non significant*

Table 4. Annual soil loss from various land uses at the four WRS during 1994-98

Slope	Dry evergreen forest	Furrow	Teak	Teak + vetiver
(1) Mae Taeng WRS				
20%	3.429	3.962	7.325	2.512
30%	1.253	7.441	6.862	4.526
40%	1.353	4.089	12.250	5.241
(2) Wang WRS				
Slope	Hill evergreen forest	Furrow	*Pinus Kesiya*	*P. Kesiya* + vetiver
20%	0.054	0.251	0.045	0.041
30%	0.043	0.217	0.067	0.048
40%	0.064	0.487	0.069	0.049
(3) Yom WRS				
Slope	Mixed deciduous for.	Furrow	Teak	Teak + vetiver
20%	0.235	0.442	0.553	0.388
30%	0.247	0.279	0.344	0.286
40%	0.251	0.321	0.584	0.329
(4) Khun Sa Than WRS				
Slope	Hill evergreen forest	Furrow	*Pinus Kesiya*	*P. Kesiya* + vetiver
20%	0.024	0.353	0.065	0.061
30%	0.032	0.173	0.087	0.083
40%	0.040	0.179	0.069	0.069

NB: Soil loss in t/ha

(space for Fig. 2)

Mae Taeng WRS
Wang WRS
Yom WRS
Khun Sa Than WRS

Fig. 2. Comparison of soil loss from various land uses in the four WRS

Table 5. Significant differences in annual runoff from various land uses at the four WRS

(1) Mae Taeng WRS

	Dry evergreen for.	Furrow	Teak	Teak + vetiver
Dry evergreen for.	-			
Furrow	ns	-		

Teak	ns	ns	-	
Teak + vetiver	*	*	ns	-

(2) Wang WRS

	Hill evergreen for.	Furrow	*Pinus kesiya*	*P. kesiya* + vetiver
Hill evergreen for.	-			
Furrow	ns	-		
Pinus Kesiya	ns	ns	-	
P. Kesiya + vetiver	ns	*	*	-

(3) Yom WRS

	Mixed deciduous	Furrow	Teak	Teak + vetiver
Mixed deciduous forest	-			
Furrow	ns	-		
Teak	ns	ns	-	
Teak + vetiver	ns	ns	*	-

(4) Khun Sa Than WRS

	Hill evergreen forest	Furrow	*Pinus Kesiya*	*P. Kesiya* + vetiver
Hill evergreen forest	-			
Furrow	ns	-		
Pinus Kesiya	ns	ns	-	
P. Kesiya + vetiver	ns	*	*	-

*NB: * = confident interval 95%, ns = non significant*

The vegetative cover influences increases in organic matter in the topsoil due to the accumulation of litter and to soil micro-organism activity. The improvement of macro porosity in the topsoil contributes to the high infiltration rate so the overland flow is minimized during the rain. As reported by Castillo et al. (1997), plant cover is a good regulator of surface runoff, especially during torrential storm events. Fogel (1976) also mentioned contrarily that vegetation removal could be considered a method for increasing water yield in semiarid regions but this involves increased flooding hazard and accelerated soil degradation. Good vegetation management practices, then, are important for protecting the soil, especially in semiarid areas, from erosion and for optimal water resource usage. This can be attributed to the effect of the multi-layered canopy, dense surface cover, and other residues in an undisturbed condition. Furthermore, the multi-layered structure of the forest (including trees, shrubs, sapling, seedling and ground cover) and the ground-covering humus or litter layer also reduce the velocity of the rain before it strikes the soil particles. However, the density of a vetiver hedge is the factor that controls and reduces the speed of the surface water flow. This results in a variety of factors, including the decreasing of runoff volume bringing higher rates of infiltration associated with better aggregated soils and the opening up of macro-pores in the soil as grass roots grow.

Conclusion and Recommendations

The results can be summarized as follows:

1. The strips planted with vetiver grass as part of the reforestation minimize runoff and soil loss, although the smallest value of soil and water loss was found in the natural forest areas.
2. The potential of vetiver grass for soil erosion control is high. The significant difference in runoff and soil loss between the reforestation intercropped with vetiver strips and the other land uses is due to the density of grass hedges, which decreases the surface flow velocity.

3. Annual runoff and soil loss from all of the treatments change over time due to the improvement of the canopy cover, undergrowth and litter accumulation. The ground surface cover and root system of the grass have primary influence on reducing soil and water losses at different values among the land uses.

These findings contribute to develop the soil erosion research technique among the grass hedges and deserve further investigation. Determination of the application of vegetative hedges for soil erosion control in the upper watersheds should be carried on in subsequent years not only through greater replication of runoff plots but also on a wider, i.e. watershed, scale.

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