Thai J. For. 17 : 1-7 (1998) วารสารวนศาสตร์ 17 : 1-7 (2541)

INFLUENCE OF RAINFALL ENERGY AND OVERLAND FLOW ON SOIL LOSS FROM TERRACED PLANTATION ON STEEP TERRAIN OF DOI ANGKHANG HIGHLAND PROJECT, CHIANG MAI

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ABSTRACT

The influence of rainfall energy and overland flow on soil loss within a plantation of 6 exotic tree-species from Taiwan, planted with narrow terracing on steep terrain was determined. Data were collected from 4x15 m, runoff plots 2, 3 and 7 years after the plantation were established. One hundred and seventy six storm events of rainfall, runoff and soil loss from each of the tree-covered plots were incorporated in to this study. A linear regression relationship between storm rainfall and rainfall energy (R_s or EI_{30} index) was found to be highly correlated with R^2 ranges from 0.86 to 0.99. Narrow-bench terraces helped to reduce overland flow and led to a low correlation between soil loss and surface runoff. R^2 which indicates the influence of surface flow on soil loss was less than 0.5 in all plantation plots in year 2 and 3, however, it was 0.92 in the bare plot. A very small R^2 was obtained when R_s was added in the analysis. It can be concluded that narrow-bench terracing and the vegetation recovery greatly reduced both rainfall and runoff energy on the steep terrain.

INTRODUCTION

Rainfall and runoff have been recognized as important factors causing soil erosion for a long time. Studies on the relationship between soil loss and runoff and between runoff and rainfall characteristics have been widely investigated in many developed and developing countries. In Thailand, the influence of rainfall energy (KE) and runoff on soil loss have been investigated in various land-uses for over 3 decades. Publication concerning this matter is still not substantial. In India, Balasubramanian and Sivanappan (1981) found an exponential rela-tionship between soil erosion and the degree of slope and rainfall. Soil erosion was profoundly influenced by both factors. The runoff and soil loss were found to increase significantly as the degree of slope increased. A significant positive relationship between KE and the maximum 30 minute intensity (EI_{30}), and the runoff and soil loss was observed. A highly significant correlation coefficient (r) between the above two characteristics indicated that it could be used for computing the rainfall factor (R) in the Universal Soil Loss Equation (USLE). The authors also concluded that runoff and soil loss were significantly reduced by mulching. Another study in India by Gupta (1981) also revealed that the simple practice of contour planting and farming cut down surface runoff and soil loss by 33 percent compared to up and down cultivation practices. Bench terracing can reduce soil loss from 41 ton/ha under shifting cultivation to only 5 ton/ha.

A study on the effectiveness of EI_{30} as an erosivity index in Hawaii showed that linear regression relationships between EI_{30} and soil loss from standard bare plots and small watersheds were well correlated. The average annual rainfall, storm daily, monthly and seasonal rainfall were also tested against the EI_{30} index. Results indicated that annual rainfall was the best estimator of the average annual EI_{30} index (Lo *et al.*, 1985). Kinnel (1985) stated that based on his experi-ments, when rilling is absent or inactive, flowing water alone can be considered minor or negligible. After surface soil crust development due to 15-20 mm of rainfall, most of the variation in soil loss was attributed to the variation in rainfall erosivity. Laboratory studies (Singer *et al.*, 1981) have

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indicated that the depth and velocity of surface-flows influence the efficiency of use of raindrop energy. The runoff rate may thus be considered as an efficiency factor affecting soil loss. A good relationship between soil loss and the product of rainfall kinetic energy and runoff rate was also found by Kinnel (1985). A study by Quansah (1985) indicated that there is a critical slope steepness at which both raindrop impact and overland flow contribute equally to detachment. At slopes lower than the critical value, raindrop impact is the main detaching agent. Flow dominates detachment on steeper slopes. The relative contribution to detachment by overland flow and splash is influenced by soil type and slope steepness. The power functional relation seems to be the most suitable for determining soil detachment rate. Slope steepness alone accounted for 37-84 percent of the variation of detachment on different soil textures combined with discharge, coefficients of determination (R^2) ranged from 0.79 to 0.96.

In this study, relationships between storm rainfall and the rainfall factor or EI_{30} index for the highland of northern Thailand and the influences of rainfall energy (EI_{30} index) and storm runoff on soil erosion in various species of fast-growing plantations with narrow terracing were determined. The derived equations are hoped to be applied for predicting storm rainfall factor, runoff potential and soil loss from such plantations on steep slopes.

MATERIALS AND METHOD

The Experimental Plots:

Single runoff plots of 4x15 m were installed for each species at the beginning of plantation establishment in 1982(Table 1). The plantations, were situated at the Doi Angkhang Highland Project, Fang District, Chiang Mai, this area is characterized by mountainous Karst topography with elevation ranges from 1,400-1,500 masl. The underlying sediments are argilaceous sediments composed of mudstone, shale, sandstone and quartzite arenaceous sediments which belong to the Devonian to Lower Carboniferous Periods. The soil classified according to U.S. Soil Taxonomy are *Typic Palehumults* and *Rhodo Paleudalfs* (Phupha-ruang, 1980). The area studied was once a hill-evergreen forest with native conifers, shifting cultivation has been carried out for more than a century. The mean annual rainfall is about 1,800 mm, and temperature ranges between 0-31°C, and relative humidity ranges between 21-98%.

Narrow bench-terraces with 2.5 m horizontal intervals were made in each species plantation except in *Paulonia* and in bare plots which were established in 1984. The site location of the investigation, including top and side views of runoff plot employed in this study are shown in Figure 1.

Table 1. Species, angle of slope, spacing and density of trees planted in runoff plots.

Species	Slope (%)	Spacing (m) & tree density (tree/plot)	
Acacia confusa Merr	60	2.0 x 2.5	12
Aleurites montana Wils.	45	2.0 x 2.5	12
Fraxinus griffithii C.B. Clarke.	55	2.0 x 2.5	12
Liquidambar formosana Hance.	50	2.0 x 2.5	12
Paulonia taiwaniana Huet Chang, sp. Nov	40	2.0 x 2.5	12
Zelkova formosana Hay.	65	2.0 x 2.5	12
Bare soil, up-and-downhill fallow	40	-	

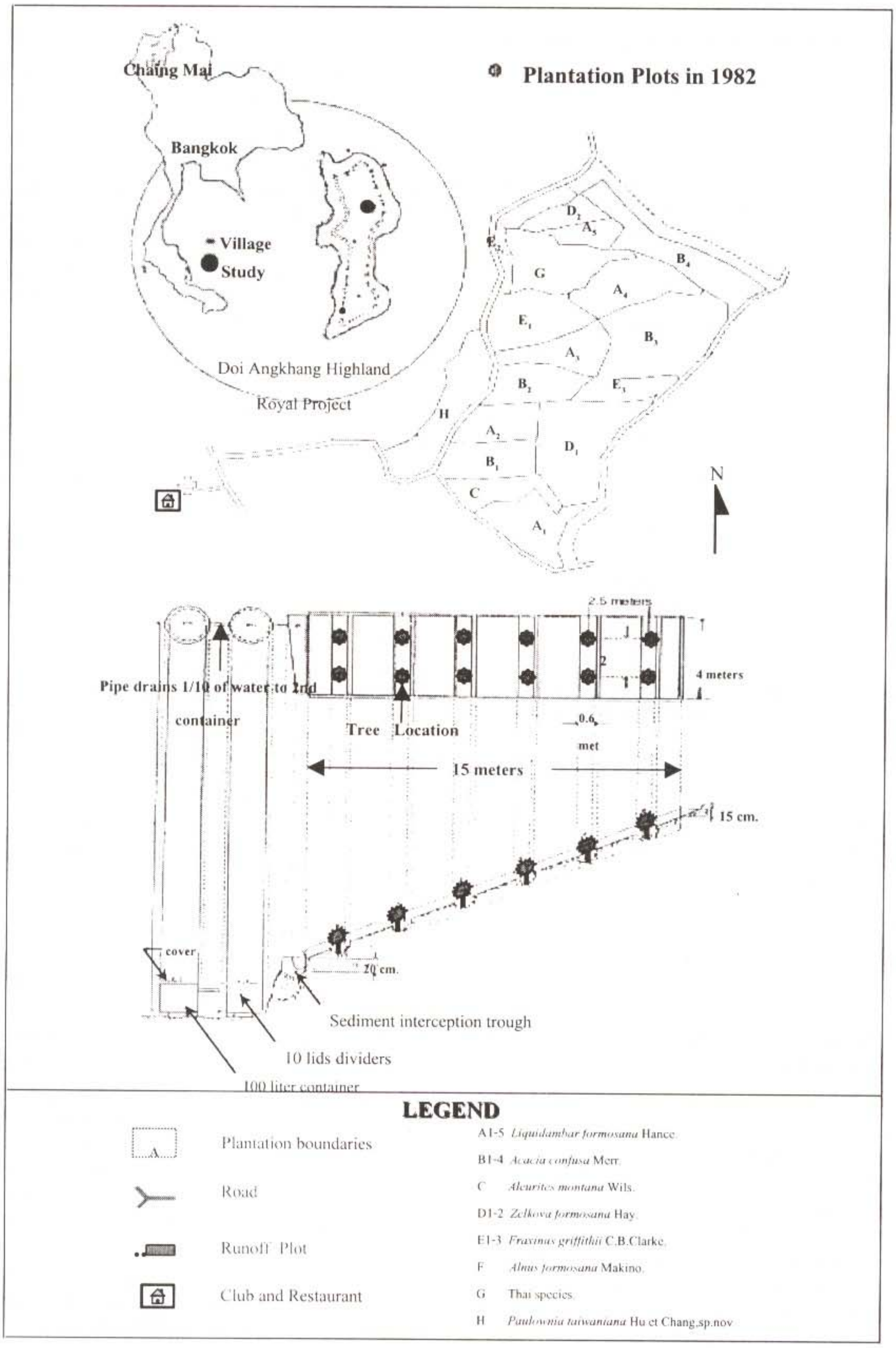

Figure 1 Doi Angkhang Highland Royal Project location and runoff plot site of various species plantations, Fang District, Chiang Mai.

Data Analysis

1) Relationship between storm rainfall and EI_{30} index or storm rainfall factor was determined by regression and correlation analysis.

2) In order to adjust the influence of slope steepness on soil and water losses, the slope-factor of equation Wischmier and Smith (1965) and the Manning Equation ($Q = VA = A[1/\eta R^{2/3} S^{1/2}]$) were applied using 40 percent slope of bare plot as a base.

3) The relationships between soil and water losses for each plantation were determined by regression analysis.

RESULTS AND DISCUSSION

Based on 58, 64 and 54 storm rainfall events, runoff and soil losses observed from runoff plots in 1983, 1984 and 1988 when the plantations were 2, 3 and 7 years old, the relationships between rainfall energy in terms of rainfall-factor and storm rainfall, between water loss and rainfall factor, and between soil loss and rainfall-runoff factors can be described as follows:

• Storm rainfall factor (R_{st}) in relation to storm rainfall (P_s)

The relationships between R_{st} (m-ton/ha) and P_s (mm) derived using the regression analysis of Jannahasatien (1986), Maknual (1991) and that of this study are presented in Table 2. It and be seen that the storm rainfall factor (R_{st}) obtained from Wischmeier and Smith's (1965) equation is highly correlated to storm rainfall whether using one-year storm or three-year storm rainfall data. This relationship seems to agree with that derived by Samran (1984) for the Kog-Ma Experimental Watershed, Doi Pui, Chiang Mai. Small variation among annual relationship was found with the coefficient (b) of storm rainfall ranges from 0.7982 to 0.9783 and intercept (a) varies from 4.683 to 8.912. An equation consisting of 176 rain storm events is recommended for prediction purposes due to its larger number of storm events and very high R^2.

Table 2. Regression equations for predicting storm rainfall factor for Angkhang Highland Project Fang District, Chiang Mai.

Year	No of storm	Equation and statistical parameters		
		Equation	R^2	F-ratio
1983[1/]	58	R_{st}=0.9783 P_s-8.912	0.8587	340.44
1984[2/]	64	R_{st}=0.7982 P_s-4.683	0.9225	738.09
1983-84[3/]	122	R_{st}=0.8977 P_s-6.6416	0.8817	894.54
1985[2/]	54	R_{st}=0.8619 P_s -5.5137	0.9976	10,638.48
1983-85[3/]	176	R_{st}=0.8869 P_s-6.3055	0.9116	1,794.63

Sources: 1/ from Janmahasatien (1986) 2/ from Maknual (1991) 3/ this study

• Relationship between Surface Runoff and Rainfall Factor

The coefficient of determination (R^2) (Table 3) indicates that the influence of storm rainfall factor on surface runoff was rather low, i.e., less than 0.3 for all plantations aged at 2-years old. The R^2 parameter was greater than 0.3 in the third year of plantation while for those plots (*P. taiwaniana* and bare-fallow) just established in the 2nd year of the study it was lower than 0.3. Generally, the storm rainfall-factor has a high influence on runoff amount for those experimental plots with an untreated land surface. The narrow bench terraces established for this purpose thus, significantly reduced overland flow caused by rain storm and led to yield a low correlation between surface runoff and rainfall-factor. Surface soil disturbed by increased porosity values permitted a higher and longer penetration of water in to deeper soil layers. The infiltration capacity of soil and the degraded terrace-shape in the following years thus caused more rainfall to be generated as surface runoff eventhough annual rainfall in year 3 was less than in year 2. The greatest surface flow values were observed in the 7th year for 4 of the 6 species.

Table 3 Relationships between surface runoff (Q_o in mm) and storm rainfall-factor (R_s in m-ton/ha-cm), and between soil loss (SS in gram) and surface runoff (Q_o mm) for year 2^{nd} and 3^{rd} year old plantations.

Plantation species	Regression Equation for	
	2-yr old plantation	3-yr old plantation
o Ralationship between Surface Runoff (Q_o) and Storm Rainfall factor (R_s)		
-*A. confusa*	: $Q_o = 0.1706+0.0034\ R_s;\ R^2 = 0.075^{*}$	$Q_o = 0.1003+0.0128\ R_s; R^2 = 0.5158^{**}$
-*A. montana*	: $Q_o = 0.1617+0.008\ R_s;\ R^2 = 0.1336^{**}$	$Q_o = 0.0323\ R_s-0.0513;\ R^2 = 0.6035^{**}$
-*F. griffithii*	: $Q_o = 0.3382+0.0105\ R_s;\ R^2 = 0.1687^{**}$	$Q_o = 0.0502+0.0212\ R_s; R^2 = 0.5087^{**}$
-*L. formosana*	: $Q_o = 0.1140+0.0056\ R_s;\ R^2 = 0.13^{**}$	$Q_o = 0.0228\ R_s-0.0255;\ R^2 = 0.3063^{**}$
-*P. taiwaniana*	: Q_o = (not planted yet)	$Q_o = 0.0453+0.2799\ R_s; R^2 = 0.2811^{**}$
-*Z. formosana*	: $Q_o = 0.0629+0.0056\ R_s;\ R^2 = 0.2687^{**}$	$Q_o = 0.0308+0.0058\ R_s; R^2 = 0.3978^{**}$
-Bare fallow plot	: (not established yet)	$Q_o = 1.1246+0.1707\ R_s; R^2 = 0.2498^{**}$
o Relationship between Soil Loss (SS) and Surface Runoff (Q_o)		
-*A. confusa*	: $SS = 36.496\ Q_o-1.89;\ R^2 = 0.4402^{**}$	$SS = 4.95+28.09\ Q_o; R^2 = 0.0557^{ns}$
-*A. montana*	: $SS = 110.19\ Q_o-11.47;\ R^2 = 0.4849^{**}$	$SS = 0.79+31.53\ Q_o; R^2 = 0.6575^{**}$
-*F. griffithii*	: $SS = 113.07\ Q_o-12.68;\ R^2 = 0.3867^{**}$	$SS = 4.06+28.05\ Q_o; R^2 = 0.2852^{**}$
-*L. formosana*	: $SS = 54.78\ Q_o-1.28;\ R^2 = 0.3751^{**}$	$SS = 6.71+36.07\ Q_o; R^2 = 0.1086^{**}$
-*P. taiwaniana*	: SS = (not planted yet)	$SS = 0.0453+0.2799\ R_s; R^2 = 0.2811^{**}$
-*Z. formosana*	: $SS = 81.31\ Q_o-0.67;\ R^2 = 0.3671^{**}$	$SS = 1.14+41.44\ Q_o; R^2 = 0.1704^{**}$
-Bare fallow	: (not established yet)	$SS = 14{,}494.40+2{,}507.50\ Q_o; R^2 = 0.9202^{**}$

Remark : Q_o = surface runoff (mm)
R_s = storm rainfall factor (m-ton/ha)
SS = soil loss (gm)

• Relationship between Soil Loss and Rainfall-Runoff Factor

The effect of rainstorm and surface runoff on water loss for each species plantation was determined using regression and correlation analysis. In 2yr and 3yr old plantations, R^2 which determines the influence of surface runoff on sediment was less than 0.5 except in *A. montana* and the bare fallow plots. Very small R^2 increase (ΔR^2) was found in all plots in year 7. Also a slight increase in R^2 was obtained when the storm rainfall-factor (R_s) was added in to the regression analysis (Table 4).

Based on the good relationship between soil loss and surface runoff for bare and fallow plots (R^2 = 0.9202), the low R^2 for plantation plots could possibly be interpreted as the role of terracing and ecosystematic function recovery due to the plantations. A longer period of study should however be carried out for a better understanding and more valid conclusions to be drawn.

CONCLUSION

The storm rainfall factor or the EI_{30} index in the USLE in relation to storm rainfall, relationship between runoff and rainstorm events, between storm sediment discharge and storm runoff combined with storm rainfall energy were observed in various types of exotic species plantations. These plantations had narrow terracing and observations were taken from six 4x15 m runoff plots with one bare fallow plot. Observed data on rainstorm, runoff and sediment when plantations were 2, 3 and 7 years old were used to analyse such relationships by regression and correlation techniques. The results show a good correlation between storm rainfall and EI_{30}-index or storm rainfall-factor with an R^2 greater than 0.85. Narrow bench-terraces built for the purpose of seedling inspection and soil and water conservation help to reduce overland flow and produced a low correlation between surface runoff and soil loss. The R^2 value which indicates the influence of surface runoff on soil loss for most plantation species, was less than 0.5. A very small increase of R^2 was found in all plots in year 7 and a

Table 4. Relationships between soil loss (SS) and rainfall (R_s)-runoff (Q_o) characteristics for various 7 yr old plantations.

Plantation species	Regression Equation for	
	SS VS Q_o and R_s	SS VS Q_o without R_s
A. confusa	: $SS = 25.18\ Q_O + 0.75\ Rs - 7.04;\ R^2 = 0.5683^{**}$	$SS = 36.24\ Q_O - 3.14; R^2 = 0.4734^{**}$
A. montana	: $SS = 0.78 + 4.18\ Q_O + 0.15\ Rs;\ R^2 = 0.5079^{**}$	$SS = 1.62 + 6.62\ Q_O; R^2 = 0.4306^{**}$
F. griffithii	: $SS = 0.60 + 7.84\ Q_O + 8.8x10\text{-}5\ R_S;\ R^2 = 0.5516^{**}$	$SS = 6.60 + 7.84\ Q_O; R^2 = 0.5516^{**}$
L. formosana	: $SS = 19.29\ Q_O + 0.12\ R_S - 0.81;\ R^2 = 0.5899^{**}$	$SS = 0.04 - 21.48\ Q_O; R^2 = 0.5799^{**}$
P. taiwaniana	: $SS = 11.90\ Q_O + 0.0035\ R_S - 0.50;\ R^2 = 0.7895^{**}$	$SS = 11.96\ Q_O - 0.47; R^2 = 0.7895^{**}$
Z. formosana	: $SS = 1.41 + 3.95\ Q_O - 0.03\ R_S;\ R^2 = 0.1932^{**}$	$SS = 1.21 + 3.23\ Q_O; R^2 = 0.1882^{**}$

Remark: SS = soil loss (gm)
Q_o = surface runoff (mm)
R_s = storm-rainfall factor (m-ton/ha)

little increase of R^2 was obtained when the rainfall factor was added in to the regression analysis.

The influence of rainfall energy and surface runoff on soil loss was low while a large R^2 (0.9202) for the relationship between soil loss and surface runoff in bare and follow plots was found. In other words, narrow bench-terrace and the ecosystematic function recovery of all plantation species greatly reduce both rainfall and runoff energy on such steep terrain.

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