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OBSERVED AND HYPOTHETICAL EFFECT OVER TIME OF THE TERRACED FOREST PLANTATION ON SOIL AND WATER LOSSES AT DOI ANGKHANG HIGHLAND PROJECT, CHIANG MAI

นิพนธ์ ตั้งธรรม*   **Nipon Tangtham**

ABSTRACT

Change of soil and water losses over time of 6 exotic-species from Taiwan namely: *Aleurites montana, Zalkova formosana, Liquidambar formosana, Acacia confusa, Fraxinus griffithic,* and *Paolonia taiwaniana* plated on 2x2.5 m spacing with narrow bench terrace at Doi Angkhang Highland Project, Fang District, Chiang Mai, was observed using runoff plots of 4x15 m installed for each species. Storm runoff and sediment were monitored in 1983, 1984 and 1988 when plantation was 2, 3 and 7-year old respectively. Observed data of soil and water losses from each plot were plotted and hypothetical function were derived for representing the effect of plantation age and terracing on soil and water losses. Result showed that although only 3 different period observation were employed to draw hypothetical trends. All hypothetical and prediction equations seem to logically explain the cause and effect of plantation ages and narrow terracing on soil and water losses of northern highland areas.

INTRODUCTION

The mountainous areas in northern Thailand have been experienced shifting cultivation for a long time. In some places like Angkhang Highland Project the mountains become denuded and abundoned for longer than century. Opium cultivation along with swidden farming has been continuously practiced during the past decades. Soil erosion and rapid flow which were the result of such successive cultivation of sloping land and without proper control measures could be accelerated (Seetisarn, 1995). It was estimated that soil loss in the highland was approximately in the range of 50 to 300 tons/ha/yr (Harper and El-Swaify, 1988). Department of Land Development reported in 1985 that top-soil loss in northern region was about 4.39 million ton/yr which was equivalent to the loss of N, P and K totally 2.6 million ton/yr (Laongsri, 1994).

During a recent field study of Giambelluca (in press), strong evidence was found that traditional swidden fields, permanent fields, abandoned fields with successional vegetation, and forest regrowth areas were observed to be of negligible importance in generating erosion-producing Horton overland flow as compared with road surface. The main reason would be those found by Zigler and Giambelluca (1995) that the mean saturated hydraulic conductivity on upaved road surface were one order of magnitude lower than on all adjacent swidden and disturbed forest lands. Unpaved road surface tended to have higher bulk density than other

* ภาควิชาอนุรักษวิทยา คณะวนศาสตร์ มหาวิทยาลัยเกษตรศาสตร์ บางเขน เขตจตุจักร กรุงเทพฯ 10903

land use types and an inverse relationship between porosity and saturated hydraulic conductivity was evident. Based on rainfall collection during investigation it was suggested that unpave road surfaces are much more likely to generate Horton overland flow than other land use types. It could be a main source areas for runoff generation and concomitant accelerated erosion in mountainous tropical watersheds.

Narrow terraces introduced to reforestation project at Doi Angkhang Project were aimed at reducing soil erosion as well as keeping more water in soil. Soil and water losses from various species plantation introduced from Taiwan were monintored and it was found that soil loss was tremendousely reduced over time but water loss tended to be increased with age (Tangtham, in press). This report aims to investigate change of soil and water losses from exotic species planted with terracing on steep terrain during investigation period. Relationship between water loss and rainfall, and between soil loss and water loss was determined. Hypothetical curves and functional relationships of soil and water loss with plantation ages were attempted so that prediction of changes on such phenomena in time could be made.

MATERIAL AND METHODS

The Experimental Plots

Single runoff plots of 4x15 m was installed for each species since the beginning of plantation establishment in 1982. The site of plantation is characterized as mountainous Karst topography with elevation ranges from 1,400-1,500 m.MSL. It was underlain by argilaceous sediments composing of mudstone, shale, and sandstone and quartzite of arenaceous sediments which belong to the Devonian to Lower Carboniferous Periods. Soil was classified according to U.S. Soil Taxonomy as **Typic Palehumults** and **Rhodo Paleudalfs** (Phupharuang, 1980). The studies area was once hill-evergreen with the native coniferous forests and converted to shifting cultivation for longer than century. Mean annual rainfall is about 1,800 mm with the temperature ranges between 0-31^{o}C and 21.98% relative humidity.

Narrow bench-terraces of 2.5 m horizontal interval were made in each species plantation except in Paulonia and bare plots which were established in 1984. Site and location of investigation including plot dimension are shown in Figure 1.

Runoff plots were installed with the following species plantation

Species	Slope (%)	Spacing (m) & tree density (tree/plot)
Acacia confusa Merr	60	2.0x2.5, &12
Aleurites montana Wils.	45	2.0x2.5, &12
Fraxinus griffithii C.B. Clarke.	55	2.0x2.5, &12
Liquidambar formosana Hance.	50	2.0x2.5, &12
Paulonia taiwaniana Huet Chang, sp. Nov	40	2.0x2.5, &12
Zelkova formosana Hay.	65	2.0x2.5, &12
Bare soil up-and-downhill fallow	40	2.0x2.5, &12

Data Collection

Data on Storm runoff and sediment in coresponding to storm rainfalls for each plot monitored in 1983, 1984 and 1988 when the trees were 2, 3 and 7-year old, and the Rainfall Factor, (R) the rainfall energy term in Universal Soil Loss Equation (USLE) as given by Wischmeier and Smith (1965), during the mentioned periods as previously presented in Tangtham (1997, in press) were employed in this study.

Data Analysis

Based on the available observed data mentioned above, (1.) relationship between soil and water losses for each plantation is determined by regession analysis, and (2) hypothetical models of soil and water losses were formulated based on observed data and trend interpolation using regression and correlation analysis.

RESULTS AND DISCUSSION

1. General trends of soil and water losses

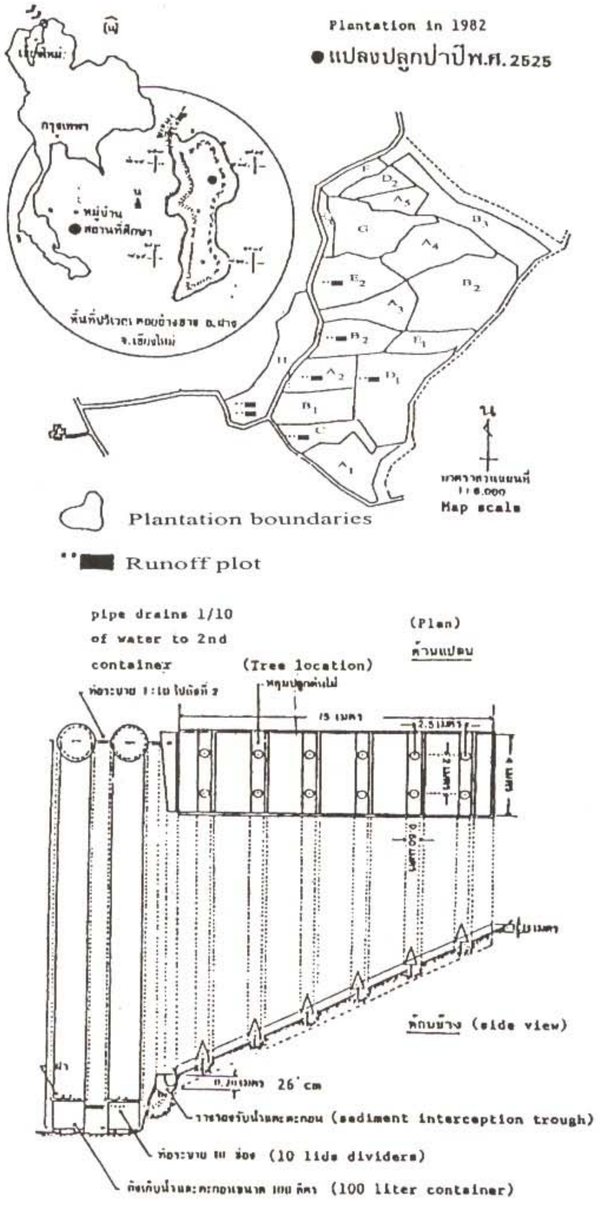
In order to determine the effect of the plantation system (combine effect of narrow bench-terraces and exotic tree species) on soil and water losses for steep terrains, soil and water losses per runoff and rainfall units were calculated and ploted for determining trends of each species. The hypothetical trends showing the effect over time were then drawn for formulating predictive models.

The observed and hypothetical trends representing the effect over time of plantation on surface runoff and soil loss were presented in Figure 2 and 3. Hypothetical models using graphic reading values of each species were thus developed and shown in the mentioned Figures.

• Chang of water loss over time

Based on water loss per 10 cm of rainfall amount observed in year 2, 3 and 7, the trend of water loss reflecting influence the age of each of plantation species and terracing can be expressed in Figure 2. The predicted values of water loss over time obtained from equations derived using observed data are presented in Table 1. Only in *P. taiwaniana* is ignored due to having only 2-yr observed data. The trends indicated that only in *F. griffithii* plot that water loss decreased from 1.89 mm/10 cm in year 2 to 1.41 and 1.33 mm/10 cm of annual rainfall in year 3 and 7 respectively. It could have the same trend for *P. taiwaniana* if the second year of water loss could be observed.

In almost all publications concerning water loss over time of reforestation, surface runoff is always reduced (Calder, 1996; Johnson, 1995; Pereira, 1973). In this study, 4 of 6 species plantation with narrow terracing yielded high corelation between water loss and age of plantation. The rain-water stored in litter-layer which was thicker in the later year together with limitation of infiltration capacity of sub-soil exposed after terracing caused larger in water loss in year 3 and 7. It could be however, generated in form of sub-surface flow or flow beneath litter layer rather than surface runoff. The reason for this explanation is that soil loss in the later years was apruptly decreased reflecting greater amount of water loss observed from plot was drained from subsurface flow. The smaller amount of sediment with larger water loss observed in those plots could be possibly caused by influence of narrow terrace which treated sediment to be deposited before reaching the end of runoff plots. It might be possible that water loss in terms of surface runoff would be decreased over time if it was separately and correctly measured. The trends such that occured in *F. griffithii* and *P. taiwaniana*



$A_{1\text{-}5}$ *Liquidambar formosana* Hance. $E_{1\text{-}3}$ *Fraxinus griffithii* C.B. Clarke.

$B_{1\text{-}4}$ *Acacia confusa* Merr. F *Alnus formosana* Makino.

C *Aleurites montana* Wils. G Thai species

$D_{1\text{-}2}$ *Zelkova formosana*, Hay. H *Paulonia taiwaniana* Hu et Chang, sp. nov.

Figure 1. Runoff plot sites in various species plantation and plot dimension at Angkhang Highland Project, Fang District, Chiang Mai, Province.

should be used to represent the influence of plantation and terracing system in Doi Angkhang Highland area.

Comparing to those water losses observed in natural forested area, water loss from this plantation techniques is greater than that of hill-evergreen forest, Doi Pui, Chinang Mai (10 mm/yr, on 20-30% slope) (Tangtham, et al, 1972) but smaller than that of 27% slope dry-evergreen forest at Chaiyapum (48 mm/yr) (Takahashi et al, 1983).

• Change of soil loss over time

In order to compare soil loss among tree species over time, soil loss per unit runoff observed when plantation was at 2-yr, 3-yr and 7-yr old for each species was ploted and hypothetical trends were drawn as shown in Figure 3. Values representing soil loss over time for each species plantation predicted from the derived equations in Figure 3 are presented in Table 3.

Soil loss from runoff plot covered by *A. montana, Z. formosana* and *F. griffithii* (Figure. 3 a, 3 b and 3 e) was sharphy reduced after 3 yr-old of plantation. At year 7, soil loss per 10 mm of surface flow of these plots was less than 0.02 ton/ha. Rate of reducing soil loss in *L. formosana* (Figure 3 c) and *A. confusa* (Fig. 3 d) is smaller than those previousely mentioned but having a larger magnitude of soil erosion at year 7 even the aboveground biomass and crown cover was grestest in *A confusa* (i.e., ≈ 30 ton/ha and 78% respectively, Table 3). If terracing contributes equal magnitude of erosion control, biomass of undergrowth seems to play some essential role in reducing soil erosion. Long-term investigation of this trend should be, however, carried out.

Although, only 3 observation were employed to derive hypothetical models. All hypothetical values seem to logically explain the cause and effect of both phenomena especially the effect of plantation ages with terracing on soil loss on the steep terrain of Angkhang area. Longer term observation is, however, planned to obtain more reliable prediction models.

Table 1. Observed and interpolated values of water loss/10 cm of storm rainfall in various species plantation at age 1-7 yr. old planted on narrow terraces, Angkhang Highland Project.

Species	Plot Slope (%)	Water loss/100 mm of storm rainfall (mm/10 cm) at Age						
		1	2*	3*	4	5	6	7**
A. montana	45	0.91	1.12	1.66	1.91	1.91	2.16	2.40
Z. formosana	65	0.28	0.59	0.49	0.83	1.02	1.20	1.42
L. formosana	50	0.66	0.77	1.10	1.19	1.37	1.55	1.71
A. confusa	60	0.44	0.83	1.23	1.62	2.01	2.41	2.80
F. griffithii	55	1.80	1.89	1.41	1.54	1.46	1.37	1.33
P. taiwaniana	40	-	-	3.48	-	-	-	1.87

Source : * Observed data by Janmahasatien (1986)
** Observed data by Maknual (1991)
Other values derived from hypothefical curves

Table 2. Observed and interpolated values of soil loss per 10 mm of water loss in various species plantation at age 1-7 yr. old planted on narrow terraces, Angkhang Highland Project.

Species	Plot Slope (%)	Soil loss / 1 cm of water loss (ton / 10 mm) at Age 1	2*	3*	4	5	6	7**
A. montana	45	0.153	0.124	0.057	0.048	0.033	0.022	0.016
Z. formosana	65	0.223	0.129	0.087	0.050	0.030	0.018	0.011
L. formosana	50	0.102	0.082	0.077	0.061	0.051	0.034	0.036
A confusa	60	0.061	0.47	0.065	0.055	0.054	0.052	0.053
F. griffithii	55	0.149	0.073	0.056	0.036	0.024	0.016	0.018
P. taiwaniana	40	-	-	0.824	-	-	-	-

Source : * observed data by Janmahasatien (1986)
** observed data by Maknual (1991)
other values derived from hypothetical curves

Table 3. Soil loss over time and cover characteristies of runoff plots under vorious species plantation with terracing at Angkhang Highland Project.

Plantation	Soil loss (ton/ha/yr) at year			Characteristics of plantation at 7 yr-old 2/			
				Crown	Aboveground biomass (ton/ha)		
	1	3	7	cover(%)	Tree	Undergrowth	Total
A. confusa	0.065	0.096	0.191	78	27.72	2.21	29.9[illegible]
A. montana	0.232	0.102	0.049	25	3.14	2.94	6.08
F. griffithii	0.469	0.124	0.028	33	8.23	1.42	9.65
L. formosana	0.105	0.102	0.080	36	6.39	1.23	7.62
Z. formasana	0.127	0.052	0.021	25	5.12	2.24	7.36
P. taiwaniana	-	-	0.044	48	-	2.78	-

Source: 1/ Janmahasatien (1986)
2/ Maknual (1991)

CONCLUSION

Hypothetical trends and prediction equations representing soil and water losses over time for various exotic species plantation planted on narrow terraces obtained from 3 different year-olds of plantation seem to logically explain effect of plantation techniques on ecohydrological function of highland areas. The revese effect of plantation age on water loss, however, needed to be reconsidered whether the loss included some of subsurface flow or only surface runoff. If the later is needed, intensive study on this matter must be further investigated. Longer period of investigation is also needed to confirm the real impact rather than the hypothetical trend.

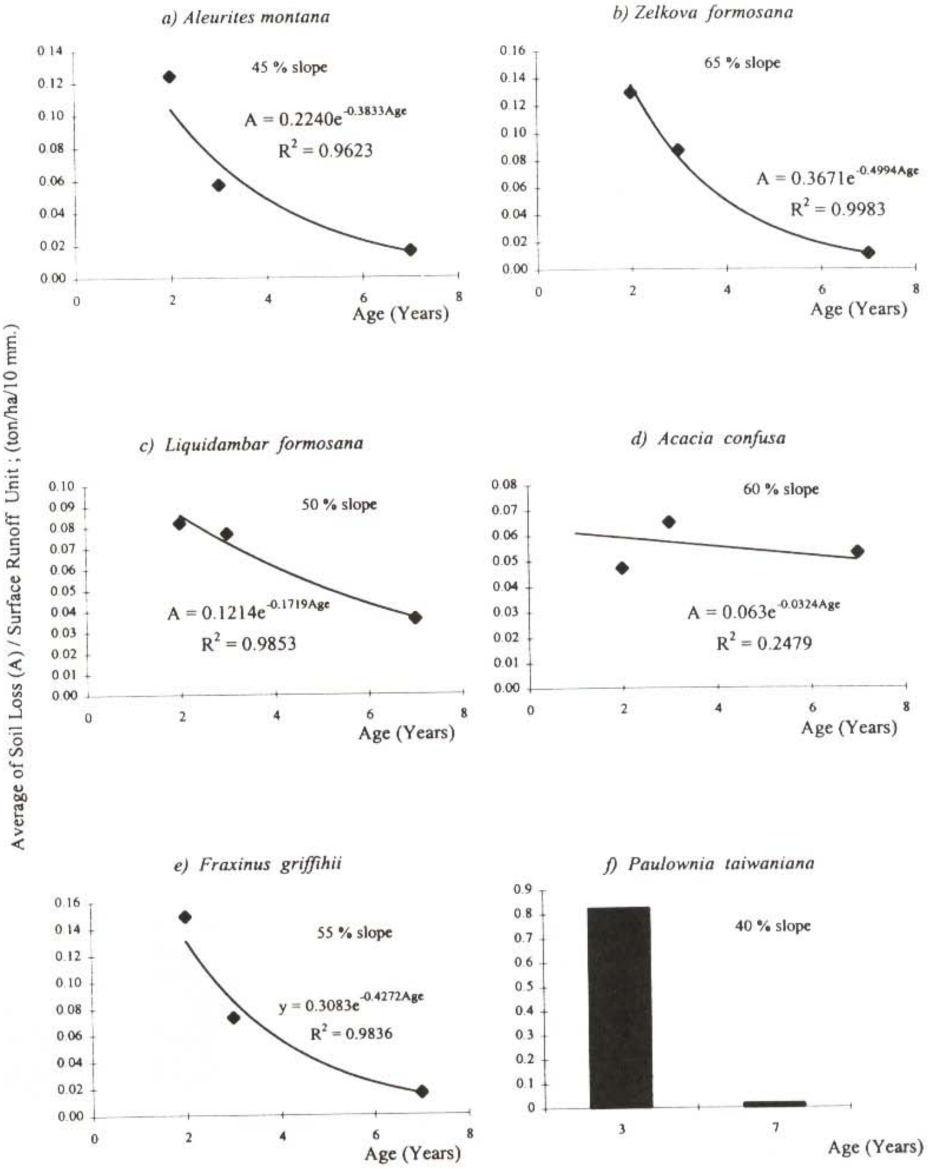


Figure 2. Observed and hypothetical effect over time of plantation with terracing on water loss of Angkhang Highland area.

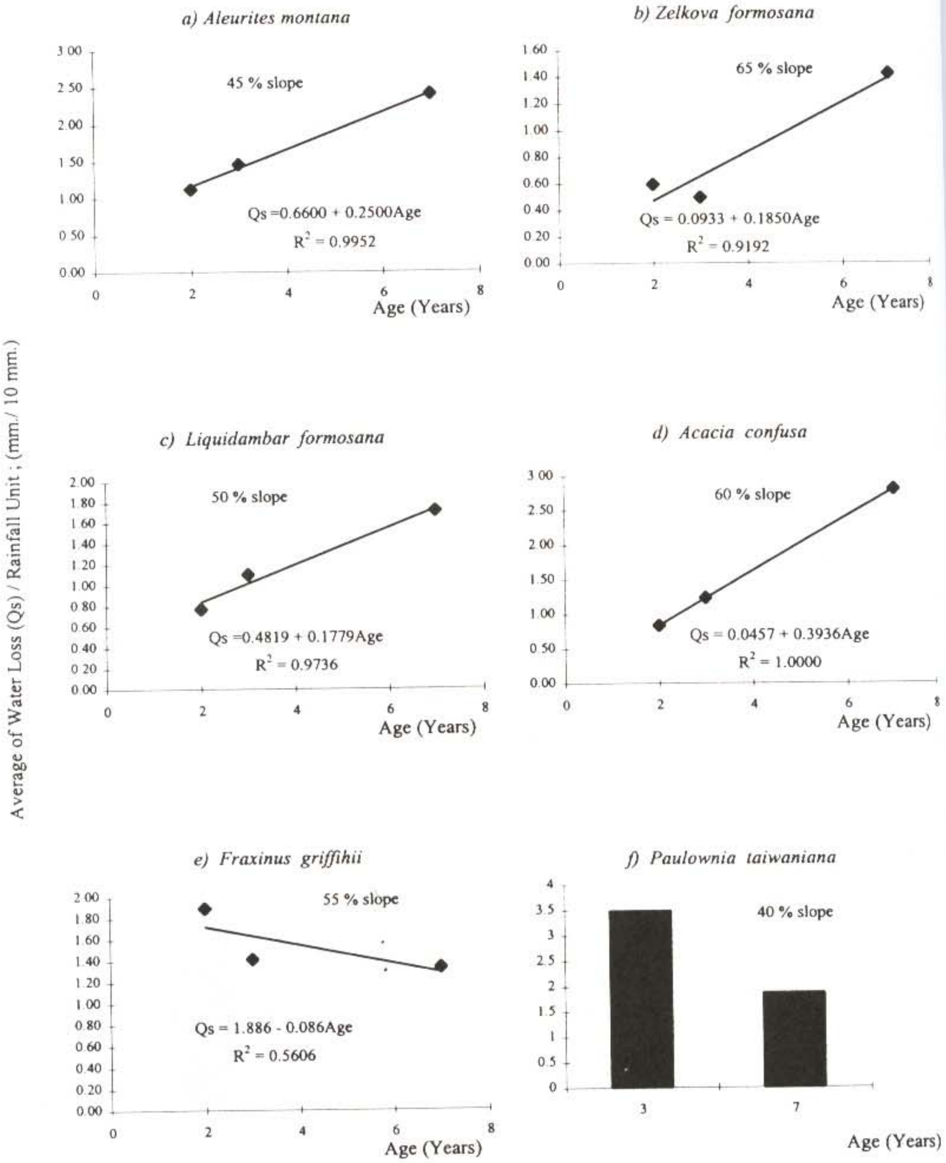


Figure 3. Observed and hypothetical effect over time of plantation with terracing on soil loss of Angkhang Highland area.

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