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SOIL AND WATER LOSSES FROM EXOTIC-TREE PLANTATIONS TREATED WITH NARROW TERRACES ON STEEP TERRAIN OF DOI ANGKHANG HIGHLAND PROJECT, CHIANG MAI

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ABSTRACT

Soil and water losses from 6 exotic-tree species from Taiwan namely : *Aleurites montana, Zalkova formosana, Liquidambar formosana, Acacia confusa, Fraxinus griffithii*, and *Paulonia taiwaniana* planted on 2.0x2.5 m spacing of narrow bench terraces at Doi Angkhang, Amphoe Fang, Chiang Mai were investigated when the plantations aged at 2, 3 and 7- year old. A single runoff plot of 4x15 sq.m was installed for each species and storm runoff and sediment were monitored in 1983, 1984 and 1988. Two additional plots were established in 1984 aiming to determine soil erodibility (K-value) in the Universal Soil Loss Equation (USLE) and to compare soil and water losses as well as efficiency of tree species and terracing in controling soil erosion (CP-factor in USLE) and surface flow. One out of two was non-terraced while another maintained in continuous fallow, periodically tilled up and down hill as a conventional corn seedbed condition and kept free from vegetation.

Results indicated that at 2-yr old, soil and water losses from the first 5 species plots were averaged at 0.2 ton/ha and 17.1 mm respectively. The losses were reduced to 0.095 tons/ha and 13.5 mm respectively at 3-yr old plantation with insignificant differences among species but highly significance between the five species and the later two plots. The average amounts of soil loss from non-terraced reforestation and conventional fallow plots were found to be about 65 and 6,600 times greater than those of the terraced plantation plots while about 4.5 and 12 times were found for water loss. When the plantation was at 7-year old, soil loss was monitored at about 0.191, 0.08, 0.05, 0.04, 0.03 and 0.02 tons/ha/ yr for *A. confusa, L. formosana, A. montana, P.taiwaniana, F. griffithii* and *Z formosana* respectively. Trend of soil loss from six- species plantation decreased with increasing ages. The water loss from the mentioned reforestated areas was measured at 36.2, 22.1, 31.2, 24.2, and 17.3 mm/yr respectively.

INTRODUCTION

In 1981, the Forest Development Administration, Vocational Assistance Commission for Retired Serviceman (VACRS) Agency of Taiwan was requested by the Royal Highland Project to introduce Taiwan fast growing trees for the purpose of mountainous rehabilitation at Doi Angkhang,

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Fang District, Chiang Mai, Northern Thailand. To obtain integrated information not only on the growth of trees but also the hydrological role of plantation techniques, Faculty of Forestry, Kasetsart University was also asked to involve in investigating soil and water conservation roles of this reforestation project.

Generally, mechanical conservation measures are popularly applied to reduce soil erosion in cropping areas. There have been a few places that use such measures in reforestation propose. In Pakistan, strip cropping, conservation benches with planting of tree on slopes, conservation benches with natural grass on slopes, and bench terraces were separately treated in four catchments. Ipil ipil (*L. leucocephala*) was planted on the risers of the bench terraces and conservation benches. In strip cropping *E. camaldulensis, Acacia modesta* and *L. leucocephala* were planted in 3 rows at 1x1 m spacing along the contour. Results of investigation showed that there was no surface runoff and sediment from catchment treated with bench terraces, while runoff andsediment were maximum from the catchment treated with only strip cropping. There was no significant difference in water and sediment benches with trees or grasses on slopes. Growth and biomass production data for ipil showed that maximum farm productivity was from the catchment treated with bench terraces (Shah, 1994).

This paper is thus the results of monitoring soil and water losses in different ages of various fast growing species plantations during the project period. The main aim of this study is to investigate soil and water losses from runoff plots covered by those introducing species over time.

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 planţation 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

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

temperature ranges between 0-31°C and 21 - 98% relative humidity.

Narrow bench-terraces of 2.5 m horizontal interval were made in each species plantation except in *P. taiwaniana* and bare plots which were established in 1984. Site and location of investigation, including top and side views of runoff plot employed in this study are shown in Figure 1.

Data Collection

1) Storm runoff and sediment in core-sponding with storm rainfalls for each plot were monitored in 1983, 1984 and 1988 when the trees were 2, 3 and 7-year old.

2) Climatic data including rainfall intensity during the mentioned periods was recorded and employed for estimating Rainfall Factor, (R)-the rainfall energy term in Universal Soil Loss Equation (USLE) as given by Wischmeier and Smith (1965).

Data Analysis

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

2) Comparison of soil and water losses among plantations was made using Analysis of Varience and LSD test.

RESULTS AND DISCUSSION

Rainfall characteristics of the investigation periods

Number of storm occuring in 1983, 1984 and 1988, when the plantations were at 2, 3 and 7 year-old, was 58, 64 and 54 storms with rainfall amount of 1644, 1193 and 1297 mm and rainfall energy expressed as Rainfall-Factor (R) of 1083, 642 and 820 m-ton/ha respectively. Storm characteristics in terms of maximum and minimum of rainfall amount and rainfall energy are included in Table 1.

Soil and Water Losses
Actual and Adjusted Losses

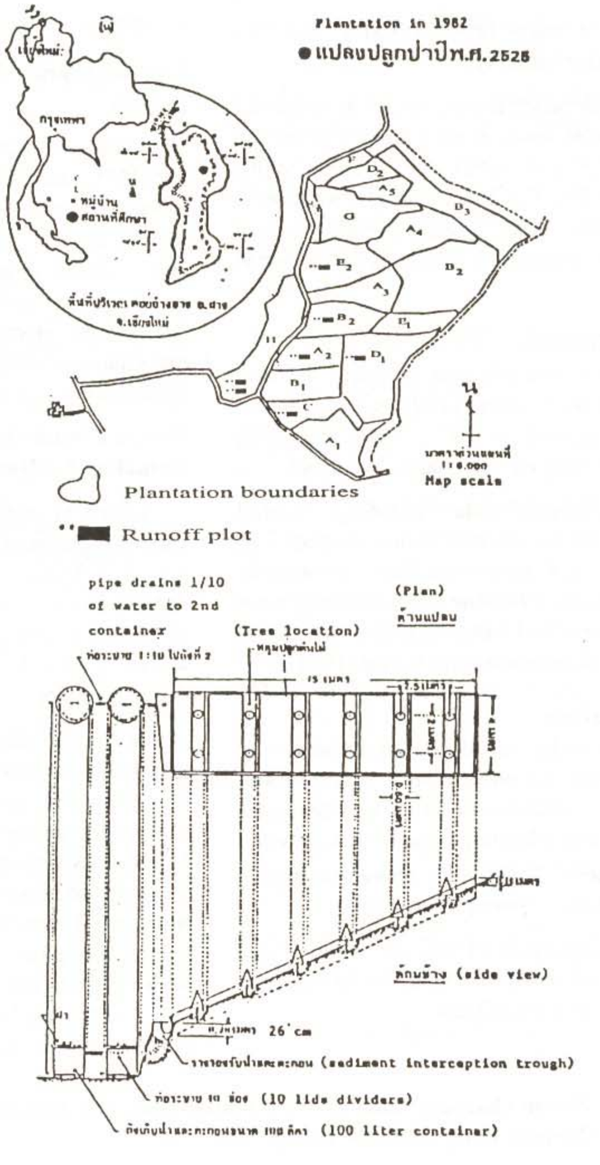
Observed soil and water losses from various experimental plots when the plantation was at 2, 3 and 7-year old were presented in Table 2. Figures in parentheses under capture of measured surface runoff and measured soil loss are at 40% slope adjusted for comparing to that of bare plot.

In year 2 after planting (in 1983), the maximum erosion of about 0.5 ton/ha was observed at *F. griffithii* plot and significant differences among plots. In year 3 (1984), the highest loss was still occurred in *F. griffithii* but adjusted maximum value was found in *A. montana*. There was, however, insignificant among tree plots excepted highly significant with the first year unterraced *P. taiwaniana* plot (3.6 ton/ha) and up-and-downhill continuous fallowed bare plot (370 ton/ha).

Table 1. Storm characteristics of the investigation periods (Angkhang Highland Project, Fang Distict, Chiang Mai)

Year	No. of storm (number)	Amount of rainfall (mm)	R-Factor (m-ton/ha)	Storm Characteristics			
				Rainfall (mm)		EI-value (m-ton/ha)	
				max.	min.	max.	min.
1983	58	1,643.5	1,082.5	74.7 1/	8.8	100.4 1/	0.50
1984	64	1,192.6	642.2	60.0 2/	1.3	44.3 2/	0.05
1988	54	1,296.7	820.1	56.2 3/	2.0	43.6 3/	0.13
Average	-	-	-	-	-	-	-

Note: 1/ early rainy season storm; 2/ mid-rainy season storm; 3/ late-rainy season storm



A_{1-5}	*Liquidambar formosana* Hance.	E_{1-3}	*Fraxinus griffithii* C.B. Clarke.
B_{1-4}	*Acacia confusa* Merr.	F	*Alnus formosana* Makino.
C	*Aleurites montana* Wils.	G	Thai species
D_{1-2}	*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.

The highest loss of water in term of surface runoff was also found in *F. griffithii* in year 2 (31 mm). It was measured at about 18, 10, 13 and 14 for *A. montana, Z. formosana, L. formosana* and *A. confusa* respectively. In year 3, only water loss from *Z. formosana* that significantly differed from other plots. Water loss from all tree plots were, however, significantly different from that from *P. taiwaniana* (42 mm) and bare plots (112 mm) (Table 2).

Table 2. Annual rainfall, rainfall-factor and soil and water losses from different ages of 6 pecies planted on steep terraces of Angkhang Highland Project .

Species1/	Slope of plot (%)	Rainfall amount (mm) and rainfall factor2/ (m-ton/ha) at age			Measured surface runoff (mm) at age3/			Measured soil loss from plot (ton/ha) at age3/		
		2	3	7	2	3	7	2	3	7
1. *Aleurites montana*	45	-do-	-do-	-do-	18.45	17.74	31.16	0.232	0.102	0.049
					(17.40)	(13.65)	(29.38)	(0.186)	(0.082)	(0.039)
2. *Zelkova formasana*	65	-do-	-do-	-do-	9.37	5.89	18.37	0.127	0.052	0.021
					(7.63)	(4.62)	(14.40)	(0.051)	(0.021)	(0.008)
3. *Liquidambar formosana*	55	-do-	-do-	-do-	12.66	13.08	22.12	0.105	0.102	0.080
					(11.32)	(11.69)	(19.77)	(0.069)	(0.067)	(0.052)
4. *Acacia confusa*	60	1643	1192	1297	13.60	14.61	36.22	0.065	0.096	0.191*
		(1063)	(642)	(820)	(11.10)	(11.92)	(29.56)	(0.032)	(0.045)	(0.089)
5. *Fraxinus griffith*	55	-do-	-do-	-do-	30.99*	16.81	17.29	0.469*	0.124*	0.028
					(26.43)	(14.34)	(14.75)	(0.259)	(0.068)	(0.015)
6. *Paulonia taiwaniana*4/	40	-	-do-	-do-	-	41.51	24.22	-	3.604	0.044
					(-)	(41.51)	(24.22)	(-)	(3.604)	(0.044)
7. Bare up & down hill continuous fallow5/	40	-	-do-	-do-	-	111.77	-	-	370.043	-
					(-)	(111.77)	-	(370.043)	-	

Notes: 1/ all species were planted in 1982 with 2.0x2.5 meter spacing density.

2/ Rainfall factor is summation of EI 30 index in USLE.

3/ Figures in parentheses indicate soil and water losses adjusted for 40% slope so that they can be compared to bare plot.

4/ Terracing was made after 3-yr old.

5/ only one year experiment. It was later replaced by *P. taiwaniana*.

Comparison based on adjusted values of soil and water losses from terraced plantations to that of unterraced *P. taiwaniana* plot and bare plot, exotic fast-growing tree plantation with terracing at 2 yr. old can help reduce about 65 times of top-soil erosion and 6,600 times if left land bared with up-and-down hill continuous fallow. These exotic-species tree plantations with bench-terraces could reduce about 4.5 and 12 times of surface runoff compared to unterraced *P. taiwaniana* with continuous fallowed bare land respectively.

In year 7 (1988), the maximum loss of about 0.191 ton/ha was measured at *A. confusa* plot. Soil loss in the other species plots was less than 0.08 ton/ha and all were much less than 12.5 ton/ha--the maximum permissible loss set by Land Development Department (1988). There was significant difference of soil loss among species. Surface runoff generated in plantation at 7-yr old was found highest (36 mm) in *A. confusa*, followed by *A. montana* (31 mm), *P. tai-waniana* (24 mm), *L. formosana* (22 mm), Z. formosana (18 mm) and *F. griffith* (17 mm) **(Table 2).** Based on annual rainfall of 1297 mm, loss of water from terraced plantation on steep slope of Angkhang area was estimated about 2% of annual rainfall after 7 years of planting.

Adjusted values of soil and water losses from all plots due to difference in slopes showed the same pattern as those of actual values. This indicates the greater influence of terraces and tree species rather than that of land slope itself.

Loss per Unit of Rainfall and Runoff

In order to evaluate the role of species and terracing on soil and water losses, soil loss in ton/ha per 10 mm of runoff was estimated for each plot. The same manner was applied for water loss but unit in mm/100 mm of rain was employed for this case. Evaluation was done for both the actual and slope-adjusted values and results were presented in **Table 3.**

Table 3. Actual and adjusted values of soil and water losses from different ages of exotic fast-growing species planted on terraced steep terrain at Doi Angkhang Highland Project .

Tree species	Slope of plot (%)	Water Loss (mm per 100 mm of rain) at Age			Soil Loss (ton/ha/10 mm of runoff) at Age		
		2 (1983)	3 (1984)	7 (1988)	2 (1983)	3 (1984)	7 (1987)
Acacia confusa : Actual1/	60	0.83	1.23	2.80	0.047	0.065	0.053
Adjusted2/	(40)	(0.68)	(1.00)	(2.20)	(0.022)	(0.030)	(0.025)
Aleurites montana	45	1.12	1.46	2.40	0.124	0.057	0.016
	(40)	(1.06)	(1.38)	(2.32)	(0.099)	(0.046)	(0.013)
Fraxinus griffithi	55	1.89	1.41	1.33	0.149	0.073	0.016
	(40)	(1.61)	(1.20)	(1.13)	(0.082)	(0.040)	(0.009)
Liquidambar formosana	50	0.77	1.10	1.71	0.082	0.077	0.036
	(40)	(0.69)	(0.98)	(1.51)	(0.054)	(0.051)	(0.024)
Paulonia taiwaniana	*40*	-	3.48	1.87	-	0.854	0.018
	(40)	-	(3.48)	(1.87)	-	(0.854)	(0.018)
Zelkova formosana	65	0.59	0.49	1.42	0.129	0.087	0.014
	(40)	(0.46)	(0.38)	(1.11)	(0.052)	(0.035)	(0.004)
Bare-up & down hill	40	-	9.37	-	-	33.11	-
fallow plot	(40)	-	(9.37)	-	-	(33.11)	-

Notes: 1/ Actual values are soil water losses observed from runoff plots in different slope gradients

2/ Adjusted values (figures in parentheses) for water loss derived based on the influence of slope on runoff generating as used in Manning equation ($Q = 1/\eta \; R2/3 \; S1/2$) and for soil loss are derived based on slope-factor (S) used in USLE ($S = 0.43 + 0.30 s + 0.043 s2$) where s is percent slope

The actual and adjusted soil and water losses values in Table 3 indicate the increasing surface runoff per 100 mm of rain with age in almost all species plantation excepted in *F. griffithii* and *P. taiwaniana*. The increase of surface runoff with increasing plantation age however indicates tremendous reduction of soil erosion in all plantations. Transport capacity of the increasing surface runoff was mainly reduced by terrace configuration and weeds as well as undergrowth in plantation. The rapid depletion of soil loss in year 2 and year 7 reflects the high efficiency of the combined effect of terraces and vegetation developed under the fast-growing plantations.

Generally, the replacement of grass or shrub cover by forest plantation always reduce surface runoff and annual streamflow from a catchment area due to more interception and transpiration loss. A review of 94 catchment experiments conducted in various countries around the world found that in every case the replacement of lower cover by trees reduced annual water yield. Reductions were greatest when the trees were evergreen, which transpire year-round on average, every 10-percent increase in coniferous cover reduced annual water yield by 40 mm (Bosch and Hewlett, 1982). One exception to this rule has been demonstrated at high elevation and in foggy areas, moisture condenses on the leaves and stems of vegetation. In the absence of vegetation, this "cloud harvesting" does not occur, and water yield is consequently lower. Another exception has been proposed by Salati *et. al.*,(1979), who argued that forests in the Amazon increase water yield because they have a positive impact on rainfall. During investigation period, annual rainfall at the experimental site tended to increase from lower than 1500 mm to 1800 mm (Boonyawat, 1995). This could be a factor causing larger runoff in the later years.

If the results obtained from this investigation were caused by the above mentioned phenomenon, the exotic fast-growing trees introduced in Angkhang highland area would be beneficial in many folds. It would increase annual rainfall which consequently increase in streamflow with good water quality (less sediment). It would also be used for fuel wood, mushroom culture, and other local industrial purposes. Such phenomenon is, however, not yet proved. Further investigation is certainly needed.

CONCLUSION

Investigation on soil and water Losses in the forest plantation with narrow terracing of exotic species introduced from Taiwan planted on steep terrain of Doi Angkhang Highland Project, Chiang Mai was carried out when plantation was at 2, 3 and 7 year-old. Six of a single runoff plot of 4x15 sq.m. were employed in measuring storm runoff and sediment caused by storm rainfall in 1983, 1984 and 1988. The results can be concluded as follows:

1) The plantation of those exotic species with narrow terracing reduced about 4.5 and 12 times of surface runoff compared to unterraced *P.taiwaniana* and continuous fallowed bare-land respectively. Water loss from each of plantation was rather small, i.e. only 2 percent of annual rainfall at 7-yr-old plantation.

2) Plantation assciated with narrow terracing reduced tremendous amount of soil erosion. When the plantation was at 2-yr-old, they help reduce about 65 and 6,600 times compared to unterraced *P.taiwaniana* and up-and-down hill bare plot. In year 7, soil loss from the plantations comparatively less than that observed in the hill-evergreen forest natively occupied in the surrounding mountains.

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