E-4.2 Evaluation of soil and fungi in restoration process

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Total Budget for FY1991-FY1995 71,383,000 Yen (FY1995; 13,278,000 Yen)

Abstract

Observations of suspended solids(SS) concentration, and surface runoff experiments in a watershed of tropical rain forest were conducted to assess mechanism of SS production. A clockwise hysteresis was recognized in relationship between discharge and SS concentration which was correlated with rainfall. Ignition loss showed an inverse relationship with SS concentration and converged at 30-40% indicating high organic content. Surface runoff on forest road during a storm produced SS concentration higher by 3 orders than that of the overland flow without rain drops. These results conclude that rain drop energy produces SS on damp areas near the stream. Approximately 130 species of wood decaying Basidiomycetes were recorded in the study site. Most species were tropical species that are restricted in tropical area, or tropical- subtropical area. Species compositions of wood decay fungi are different according to the substrata size. Species on smaller substrata were less affected by water potential and were suggested to be more tolerable against drought stress. Some species were suggested to be specific on Dipterocarpaceae species but most of very common species were probably not host specific. In many cases, single species colonized wide areas of single fallen trees. Most isolates obtained from different basidiocarps belonged to different clones that suggested populations of wood decay fungi on single trees are composed of mycelia that belong to a number of smaller genets in many cases.

Key Words restoration process, SS production and transport, decomposition, wood-decay-fungi

1. Introduction

Deforestation is the main cause of sediment production which adversely affects tropical rain forest ecosystem. Based on the earlier studies on the effect of deforestation to sediment yield, it is concluded that conversion of forest to cultivated land may: (i) increase sediment density and dissolved load in surface runoff and interflow; (ii) accentuate soil compaction and structural degradation; and (iii) decrease soil organic matter. Surface erosion in tropical rainfall forest is generally low. However a detailed mechanism of SS production and transport in natural forests is not fully understood. Evaluation of natural tropical rain forest on SS production is useful to comprehend SS effects on sequential forest-stream ecosystem.

Wood decaying fungi were important agents in decomposition of woody litter. However, most of the present studies on wood decaying fungi were on taxonomy or biogeography, and ecological studies of wood decay and decaying fungi in tropical regions are not well presented. In this research, we are studying the community developments of wood decay fungi and their ecological roles in a tropical rain forest. To grasp flora of main wood decay fungi in the site, determination was made for the collections obtained from the site. To study community developments of wood decay fungi, effect of substrata size and species on community of decay fungi on them were studied. To study population structure and dispersal of wood decay fungi, clone analyses on fallen trees were made. For the study of wood decomposability, decay test were made in laboratory.

2. Methods

2.1. Soil

Study site of Bukit Tarek Experiment Watershed is located on low land hill in the center of Peninsular Malaysia(Lat. 3 ° 31 N., Long. 101 ° 35 E). The forest of the study area is the secondary natural forest, where *Koompassia malaccencis*, *Eugenia spp.*, and *Canarium spp.* are the dominant species. Forest surrundings are converted to rubber, oil palm, and *Acacis mangium* plantations. Annual mean precipitation from 1992 to 1994 of the study area is 2,414mm. There are two mager peaks of monthly precipitation in May and November, which are reflected by the monsoon [1]. Rainfall at Bukit Tarek is characterized by high intensity and short duration. Soil water retention curves of B and C horizons show high values at residual, implying fine and poorly-graded particles of soil that resulted in high cohesiveness.

These properties of soil and rainfall may play an important role in surface runoff and SS production processes. In order to capture the rainfall and the discharge response in detail, a sensitive rainfall intensity sensor (0.0083 mm/pulse) and a digital water level sensor with high resolution have been added to the hydrological monitoring system at the weir of C1 in Bukit Tarek and monitored at 5 minutes interval. Electric conductivity(EC) and dissolved oxygen(DO) of stream water are also measured in C1 at 5 minutes interval.

The peak of SS concentration during a storm event usually precedes water discharge in small catchments [2]. As we mentioned before that the high intensity rainfall and short duration of rainfall in Bukit Tarek which is generally the case for another humid tropical regions requires temporal changes of SS to be measured at short time intervals in order to fully assess the sediment discharge and water quality response. A combination of two water sampling systems was installed at the weir C1. One is triggered by a rainfall intensity sensor and collects samples at five minute intervals, and the other samples stream water at two hours of regular intervals. SS were determined by gravimetric method. The dried residues of SS were then ignited in muffle furnace at 550 –700 ° C. The further loss weight due to combustion of organic matter provide the loss ignition expressed as percentage. In addition to the observation at the C1 weir, artificial surface runoff experiments [3] (length<1.0m, width=0.2m), on forested hillslopes and a forest road were conducted to measure Mannings roughness coefficient. On the forest road, temporal sediment discharge during a natural storm was also measured.

2.2. Fungi

2.2.1. Flora of wood decay fungi

Collection of wood decay fungi were made within Ecological Plot 1 and other area of Pasoh Forest Reserve. Collected specimens were examined macroscopically and microscopically, them determined to species or genera.

2.2.2. Effect of substrata size on community of wood decay fungi

Four plots were set up in Pasoh Forest Reserve. All woody litter wider than 2 cm were examined in the plots. Species of wood decay fungi on each litter and mean diameter of it were recorded. To investigate the effect of water potential (WP) on the growth of wood decay fungi, isolations were made for main species and growth of each fungi was studied. WP of the meidum was controlled by the addition of KCl and checked with a calibrated dew point microvoltmeter. Media with 10 different KCl concentrations were used for each fungi. Five replicates were made for each treatment.

2.2.3. Host specificity of wood decay fungi

In and around Plot 1, determination was made for wood decay fungi on fallen trees whose names were known.

2.2.4. Clone distribution of decay fungi on fallen trees

Clone distributions were analyzed for wood decay fungi colonized in wide area of single fallen trees as follows: Tree I (species name unknown) colonized with *Phellinus lamaensis* and *Pyrofomes* sp.; Tree II (*Triomma malaccensis*) colonized with *Ganoderma australe* ; Tree III (*Scaphium macropodum*) colonized with *Ganoderma* sp. and *Rigidoporus microporus* and Tree IV (*Dipterocarpus sublamellatus*) colonized with *Ganoderma australe* and *Erythromyces crocicreas*. Isolations were made from basidiocarps or pieces of decayed wood attached with basidiocarps and following isolates were obtained: 10 isolates of *P. lamaensis* from Tree I; 12 isolates of *G. australe* from Tree II; 3 isolates of *G.* sp. and 2 isolates of *R. microporus* from Tree III; 3 isolates of *G. australe* and 5 isolates of *E. crocicreas*. Clone distribution of wood decay fungi was analyzed with somatic incompatibility test in a sawdust-rice bran medium.

2.2.5. Wood decomposability

Isolations of common species in the study site were made (22 species). Using these isolates and JIS tester isolates of Trametes versicolor and Fomitopsis palustris, decay test were made in laboratory. Five test piece of Fagus crenata (20 x 20 x 15 mm) were buried in sawdust-rice bran medium prepared in plastic bottles. Inoculations were made on autoclaved media. After incubation for 6 months, test pieces were taken, dried and weighed. Weight loss rate was calculated.

3. Results and Discussions

3.1. Soil

During the observation period of November 1992 and November 1993, there were four storm events from which we obtained the data. Table 1 summarizes these storm data. Fig. 1 shows the rainfall intensity, water discharge, EC, DO, SS concentration and SS discharge of storm. Peaks of water discharge and EC shows larger time gaps to rainfall peaks than DO. because the discharge in early stage of storm is formed by rain water containing high dissolved oxygen. Contrary to this, the stream water showing high value of EC originated from subsurface water forms main storm flow and generates time gap from rainfall, because of relatively longer flow passway in the top soil. SS concentration rose quickly and preceded that of stream discharge like DO fluctuation.

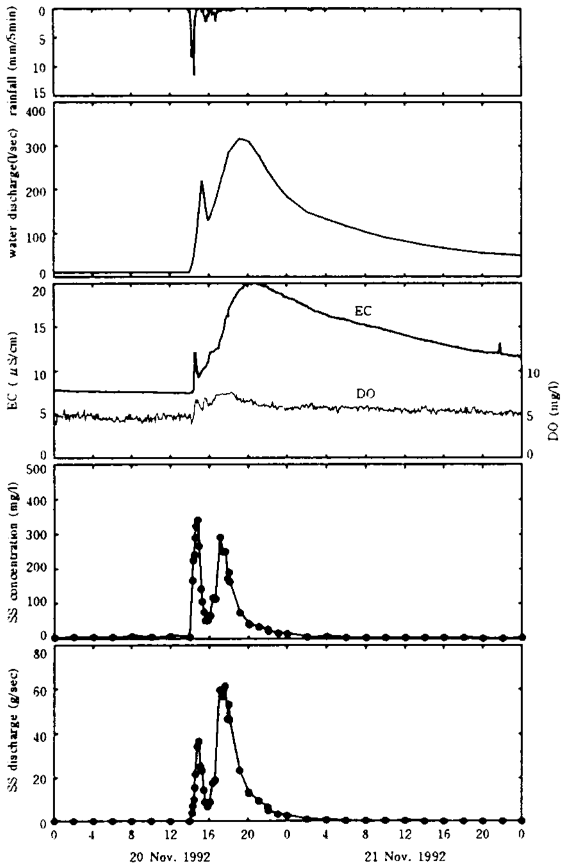

Fig. 1 Observed fluctuation of rainfall intensity, water discharge, EC, DO, SS concentration and discharge.

A clockwise loop of hysteresis [4] exists in the relationship between SS and water discharge(Fig. 2). Magnitudes of the hystereses are in proportion to the storm sizes. The clockwise hysteresis should be regarded as the evidence of differences in time and space between SS production and water discharge generation, if the catchment and stream power is relatively small such as Bukit Tarek Experiment Watershed. Rainfall intensity was selected as a well - correlated parameter with SS concentration in order to analyze the SS production mechanism.

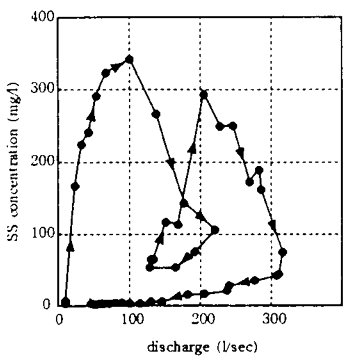

Fig. 2 Relationship between discharge and SS concentration.

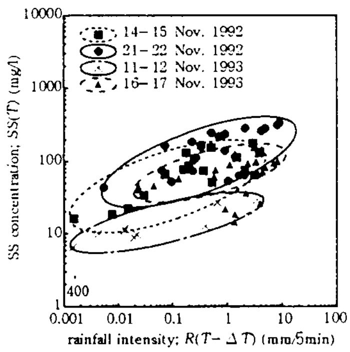

Fig.3 Relationship rainfall intensity and SS concentration.

Assumed ΔT as an arrival time of first peak of SS from source to measuring point, and also assumed L as the distance between source and measuring point. As produced SS flows upon the stream water, ΔT was calculated with velocity of stream flow(v) obtained from the value of water discharge(Qin) with Mannings formula(Eq.(1)), where l is the width of the stream, h is the depth of stream water, n is the roughness coefficient, i is the gradient of the stream bed.

$$\Delta T=\frac{L}{v}=\frac{L\cdot l\cdot h}{Qin}=(L\cdot l^{0.4}\cdot n^{0.6}\cdot i^{-0.3})\cdot Qin^{-0.4}=aQin^{b} \qquad (1)$$

Parameters of a and b are 45.3(units of Qin and are l/s and minute respectively) and −0.337 with the obtained gap time data. Obtained value of b is close to the theoretical one of −0.4.

Fig. 3 shows the relationships between rainfallintensity and SS concentration. The value of SS concentration correlates positively with the value of rainfall intensity, and a liner relationship in logarithmic axes is obtained in each storm event(eq.(2)).

$$SS(T)=c\{R(T-\Delta T)\}^{d} \qquad (2)$$

where, SS (T) is SS concentration at time T, $R(T-\Delta T)$ is rainfall intensity at the time of $T-\Delta T$, and $c\cdot d$ are the parameters which are varied with storm events. The parameters of $c\cdot d$ are also dependant on the initial discharge of Qin, showing negative correlation. Soil detachment by rain drop impact contribute significantly to sediment production with surface sheet flow [5), 6), 7)], however, the deeper flow than 1 cm protects the soil detachment by the rain drop energy. These phenomena affect the dependence of $c\cdot d$ on Qin. Fig. 4 shows the relationship between observed and estimated SS concentration.

Fig. 5 shows the relationship between SS concentration and loss on ignition. The loss on ignition converges at 30 − 40% level, indicating high organic matter content in SS, and show an inverse relationship with SS concentration. This means the source of high SS concentration differs from that of low SS concentration. The source of SS in Bukit Tarek at the peak is not confounded rarely to the stream bed, because the minimum loss on ignition exceeds 30%, indicating a relatively high organic content compared with bedload gravels.

The experiment results are summarized in Table 1. Inflow during the runoff experiment on forested hillslopes from a reservoir tank was set at the maximum (5 l/min equal to 1500mm/h intensity), because of the extremely high infiltration rate. However, overland flow may not occur on the forested hillslope under normal storm condition. On the contrary, infiltration rates on the forest road were very low and produce significant amount of overland flow.

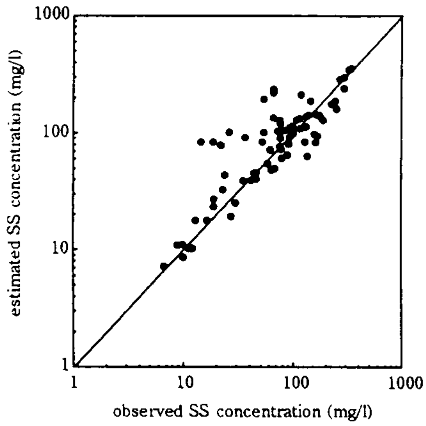

Fig. 4 Observed and estimated concentration.

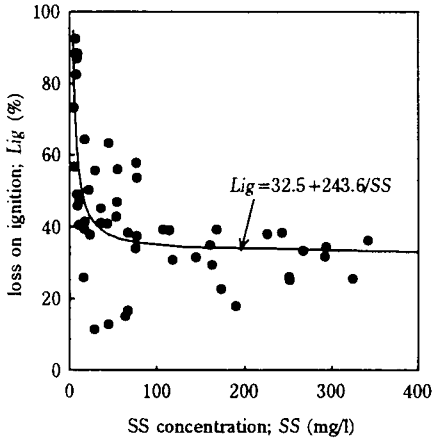

Fig. 5 Relationship between SS concentration and loss on ignition

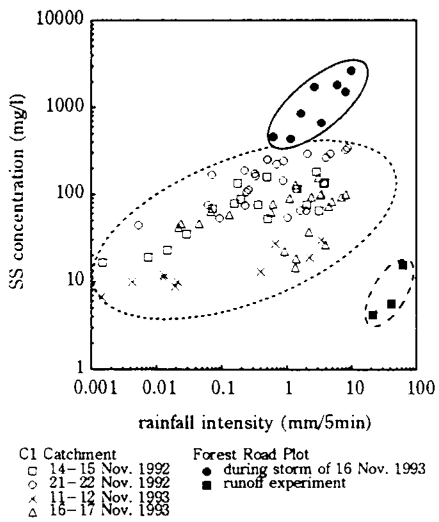

Fig. 6 Relationship between rainfall intensity and SS concentration.

Table.1 Results of runoff experiment on forested hillslope and forest road.

Plot #	surface condition	velocity v(cm/s)	hydraulic radius h(cm)	slope gradient I(sin θ)	roughness n($m^{-1/3}$/s)	SS (mg/l)
1	humus	6.395	0.2450	0.2867	0.03279	8.8
	bare	21.053	0.1146	0.2867	0.00600	-
2	humus	5.618	0.1113	0.4040	0.02617	4.7
	bare	29.520	0.0982	0.4040	0.00458	24.9
3	road	7.475	0.1236	0.1405	0.01245	4.3
		10.602	0.1685		0.01079	7.4
		13.564	0.1981		0.00939	15.3
		16.181	0.2409		0.00897	-
		18.684	0.2336		0.00761	-

The sediment concentration during a storm event on the road were higher than that of sheet flow of the artificial experiments by about 1000 times (2 to 3 orders) of magnitude (Fig. 6). The different conditions between the natural storm and artificial runoff experiments on the road only concern detachment by rain drop impact.

The observed results, i.e., clockwise hysteresis, positive skip between rainfall intensity and SS concentration, and negative relationship between loss on ignition and SS, provide important information for explaining the SS production mechanism. The source of high SS concentration must be located close to the stream, because immediate transport of SS from source to sampling site, which is obtained from short time gap between the peaks of rainfall intensity and SS concentration and the high rate of infiltration on hillslopes. Furthermore, sheet flow must occur at the SS source area during storm events for the quick delivery of the produced SS to the stream. As wet strips on the bank touching the stream and especially swampy areas around the stream satisfy these requirements, this could be a source for SS production. In Bukit Tarek, such kinds of wet strips and damp patches can be observed near the main stream.

L of the distance between the source area formed first peak of SS concentration and the measuring point was calculated to be 309.7 m by eq.(3) which is transcribed from eq(1), where *a*, *i*, *l* and *n* are *205.8*, *1/37*, *3* and *0.04* respectively.

$$L=a\cdot l^{-0.4}\cdot n^{-0.8}\cdot i^{0.3} \qquad (3)$$

Fig. 7 shows the cross section of stream bed of the catchment. The estimated source of SS is located at gentler part of the stream, where the damp patches exist. The Damp areas correspond with the so-called contributing area [8] of water discharge, and the weak hysteresis of small storm verifies this hypothesis. However, the variable source area concept [9, 10] of water discharge, which is extended from the partial area concept based on the contributing area, cannot be applied to SS production, because the source area of SS production disappears when rainfall stops, whereas the source area of water discharge is still expanding. Consequently, the SS production is limited by the impact energy of rain drop in the earlier stages of the storm and also limited by the source in the later stages of the storm. The SS source which is strongly related with rainfall generates a clockwise loop of SS concentration and water discharge. Heidel [2] reported that the peak of sediment concentration usually occurs prior to that of water discharge in the small catchment, the hypothesis seems general in small catchments of humid regions.

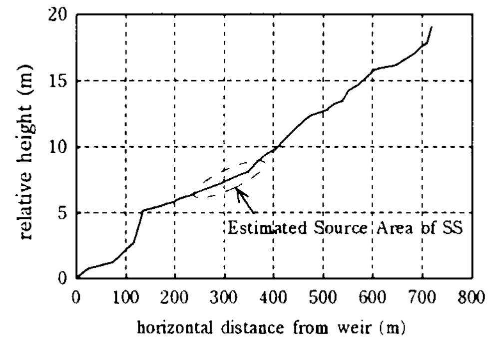

Fig. 7 Cross section of stream profile of C1 experiment watershed in Bukit Tarek

3.2. Fungi

3.2.1. Flora of wood decay fungi

About 130 species of wood decay fungi (Polyporaceae, Hymenochaetaceae, Ganodermataceae and part of Corticiaceae) were hitherto known from the study site. Among them 7 species are common to temperate area, 20 species are common to warm temperate area and 22 species are common to subtropical area of Japan. Many of other species are suggested to be restricted in tropical area.

3.2.2. Effect of substrata size on community of wood decay fungi

Among the frequent species basidiocarps of following species were mostly produced on smaller substrata: *Earliella scabrosa; Hexagonia tenuis; Microporus carneoniger; M. xanthopus; Stereum ostrea; Porostereum crassa; Coriolopsis retropicta; Megasporoporia cavernulosa.* Other species as follows were mostly on larger substrata: *Erythromyces crocicreas; Fomitopsis carnea; Ganoderma australe; Nigroporus vinosus* and *Phellinus lamaensis.*

Mycelial growth of the species on smaller substrata (SSS) were similarly affected by WP. Except for H. tenuis, the growth rates decrease to half optimal at the WP around or below −2.2 MPa and cease below −6.7 MPa. Among the species on larger substrata (SLS), *P. lamaensis* showed a similar trend to SSS. Except for this species, the growth rates were more affected with WP, decrease to half optimal at a WP of above −2.2 MPa and cease above −6.7 MPa.

The results indicated above suggests that mycelial growths of SLS were more affected by WP than those of SSS. Within a medium with low WP, water availability is lower than in a medium with high water potential. Therefore, SSS are more tolerant against drought stress than many of SLS.

3.2.3. Host specificity of wood decay fungi

Ganoderma australe were hitherto recorded on 10 species (7 families) of fallen trees and suggested that its host range is wide. Other species indicated below were also recorded on trees that belong to more than 2 families and probably not host specific, also: *Daedalea* cf. *aurora, Ganoderma* sp., *Loweporus fuscopurpureus, Microporus affinis, Nigroporus durus, Phellinus lamaensis, Polyporus grammocephalus, Trametes elegans.* On the other hand, species indicated below were suggested to be restricted on Dipterocarpaceae trees: *Erythromyces crocicreas, Fomitopsis carnea, Fomitopsis dochmia* and *Perenniporia* cf. *meddulaepanis.* It is known that many of wood decay fungi in temperate area are host specific. In this research site, many of common species are probably not host specific except for some species that are restricted on Dipterocarpaceae trees.

3.2.4. Clone distribution of decay fungi on fallen trees

From Tree I, 10 isolates of *P. lamaensis* were obtained from the basidiocarps attached on the range between the base and the position 15.5 m above the base of the tree. Isolates Pl I−2 and Pl I−3, 3.5 m apart from each other and Pl I−1 and Pl I−5, 4.0 m apart from each other belonged to the same clones, respectively. Other isolates belonged to different clones.

All of the *G. australe* isolates from Tree II, *G.* sp. and *R. microporus* isolates from Tree III and *G. australe* and *E. crocicreas* isolates from Tree IV belonged to the different clones. In this research, most of the isolates were colonized separately through basidiospore infections. Probably many of these isolates were sib isolates and infected with basidiospores from the same or a few basidiocarps produced on or near the trees.

3.2.5. Wood decomposability

Most species examined showed wood decomposability on *Fagus crenata* test pieces. *Earliella scabrosa, Ganoderma australe, Microporus xanthopus, M. affinis* and *Nigroporus vinosus* showed more than 50 % weight loss that were almost equal or stronger decomposability by the tester fungi. However, decomposabiilty by *Fomitopsis carnea, F. feei, Grammothele lineata, Hexagonia tenuis* and *Phellinus caryophylleus* were less than 5.4 %. Most of the early colonizer on fallen trees showed strong wood decomposability.

4. Conclusions

Intense observation of rainfall, suspended solid concentration and simple surface runoff experiments on both forested hillslopes and forest road were conducted in a small forested watershed in Bukit Tarek, peninsular Malaysia. A clockwise hysteresis loop was recognized in the relationship between SS concentration and water discharge, and SS concentration positively correlated with rainfall intensity. Solids concentration during a storm event shows 3 orders of magnitude higher than that of an artificial overland sheet flow experiment without rain drop of the forest road site. These results conclude that the SS source exists near the stream, and it could be strips along the stream and damp areas which corresponds with the so-called contributing area of water discharge. A hypothesis that a damp area close to the stream in a small catchment is a contributing area of suspended solid requires wide-ranging field observations to be verified. Discussions over the hysteresis phenomenon and source area of SS, that take catchment scale and stream power into consideration, have been few. Investigation balancing of tractive stream power and rain drop energy related to catchment scale will be necessary for the argument of the suspended solids issue.

Approximately 130 species of wood decaying Basidiomycetes were recorded in the study site. Most species were tropical species that are restricted in tropical area, or tropical-subtropical area. Species compositions of wood decay fungi are different according to the substrata size. Species on smaller substrata were less affected by water potential and were suggested to be more tolerable against drought stress. Some species were suggested to be specific on Dipterocarpaceae species but most of very common species were probably not host specific. In many cases, single species colonized wide areas of single fallen trees. Most isolates obtained from different basidiocarps belonged to different clones that suggested populations of wood decay fungi on single trees are composed of mycelia that belong to a number of smaller genets in many cases.

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