Impact of forest management system on runoff and soil erosion in a tropical Indonesia rainforest

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1. Introduction

Indonesia is one of the countries which have a large of forest area. It covered 60% of total area or 10% of total world tropical rainforest. Land conversion and illegal logging are threatening the biodiversity and hydrological cycle in particular runoff and soil erosion at forested area. Indonesian forest is managed by silviculture systems. The selective logging and intensive line planting, or *Tebang Pilih Tanam Indonesia Intensif* (TPTII), is the latest forest management system, started in 2002.

Timber extraction using heavy machines destroys the soil structure that plays an important role in water and nutrient cycling, accelerating the soil erosion rate. Heavy machines in timber collection areas and on skidder roads increase soil compaction by up to 40% [1], and 10-30% of the soil surface may be laid bare in the form of logging roads, skidder tracks and log landings [3]. In a previous study, the infiltration capacity of a tropical rainforest 1 year after TPTII treatment decreased to 81.8% of a virgin forest [2].

Many studies have considered runoff and soil erosion of plots with different land cover, but information on the direct impact of selective logging and intensive line planting in tropical rainforests remains limited. Therefore, in this study, we quantified and compared the direct runoff and soil erosion among virgin forest and two line plantations.

2. Methods

2.1 Study site

This study was conducted in tropical rainforest at the Sari Bumi Kusuma company concession area, a private forest in Central Kalimantan, Indonesia. This location is part of the high-biodiversity area known as the "Heart of Borneo". The study site was located in the headwater region of the Katingan watershed, one of largest watersheds in Central Kalimantan.

According to the forest climate classification system of Schmidt and Ferguson, the area is a type A (very wet) tropical rainforest (monthly average rainfall > 100 mm). The mean annual precipitation for the period 2001–2009 was 3,601 mm, with the highest average monthly precipitation (367 mm) occurring in November and the lowest average monthly precipitation (183 mm) occurring in August. The mean temperature is 30ºC–33ºC at noon and 22ºC–28ºC at night.

2.2 Forest management system

The intensive line planting is implemented after selective logging of about 25% of the forest; the rest (75%) is maintained in its natural condition for biodiversity purposes. The scheme of the TPTII system is shown in Fig. 1.

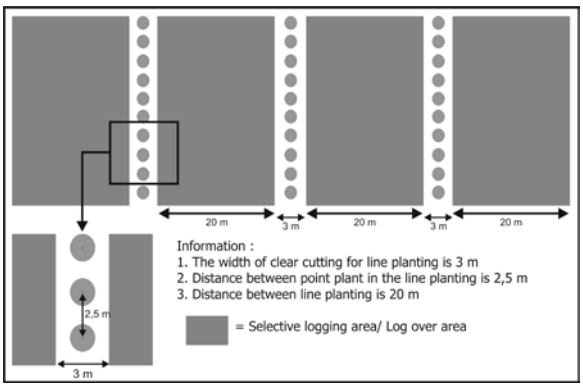

Fig. 1: Scheme of plantation in the TPTII

Typically, about 200 seeds per hectare are planted, and the expected standing stok at the end of the rotation (30 years) is around 400 m^3 per hectare, assuming 160 trees per hectare with an average diameter of 50 centimetres (or 2.5 m^3 per tree).

TPTII implementation decreased the number of trees per hectare. In the virgin forest, the percentage of canopy trees cover was 80.1%. After selective logging and intensive line planting, it decreased to 49.3%. The implementation of TPTII decreased the canopy trees cover by 38.5%.

2.3 Research catchment

This research was conducted at three small catchments with different forest canopy cover densities: a virgin forest, a1-year-old line plantation, and a 10-year-old line plantation. Hereafter, these catchments are referred to as the "virgin forest catchment", the "2008 catchment" and the "1999 catchment", respectively. The catchment areas of the three were 110.33, 191.54 and 149.49 hectares, respectively.

2.4 Field observation and analysis

A weir was installed at each catchment outlet. Rainfall data were collected from a weather station and 2 manual rain-gauges. At 3 m wide of weir, we devided into 3 sections then measured the suspended sediment on several water level variation by a suspended sampler.

During the research period (June 2009–June

2010), we selected several paired of rainfall and hydrograph data at each catchment. We found 38 paired data in the virgin forest catchment, 67 paired data in the 1999 catchment and 42 paired data in the 2008 catchment.

We separated the discharge hydrograph data into direct runoff and baseflow using a straight-line method. Furthermore, we calculated the direct runoff and erosion for each hydrograph.

3. Result and discussion

3.1 Runoff characteristics

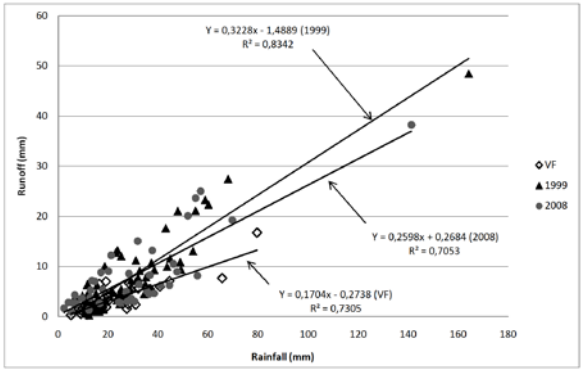

Fig. 2: Relationship between rainfall amounts per event and direct runoff

Fig. 2 shows the total direct runoff was lowest in the virgin forest catchment, and highest in the 1999 catchment, which was only slightly higher than that in the 2008 catchment. Accordingly, the average direct runoff (and percentage of rainfall as runoff) in the virgin forest, 1999 catchment and 2008 catchment was 3.62 mm (15.4%), 7.44 mm (25.3%), 8.03 mm (31.3%) respectively. Hence, the direct runoff rate in the 1999 catchment and 2008 catchment was 2.05 and 2.22 times that of the virgin forest catchment, respectively.

3.2 Discharge of suspended sediment and soil erosion

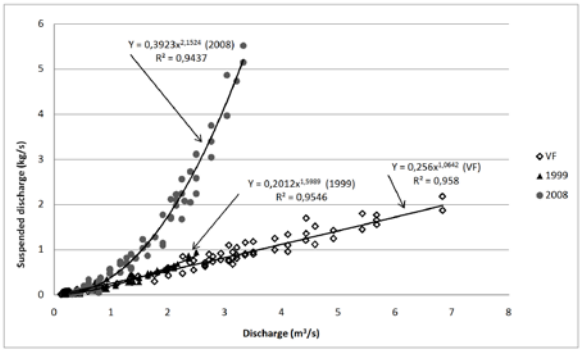

Fig. 3: Discharge of suspended sediment

Fig. 3 shows the relationship between water discharge and suspended discharge. The suspended discharge was significantly higher in the 2008 catchment than in the virgin forest and 1999 catchments. Timber extraction has proved to increase the suspended sediment.

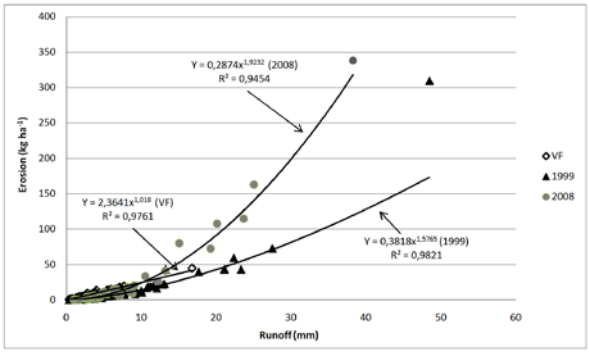

Fig. 4: Relationship between direct runoff and soil erosion

Fig. 4 shows the relationship between direct runoff and soil erosion in the three catchments. There was a strong relationship between the two, and soil erosion was significantly higher in the 2008 catchment (28.91 kg ha^{-1}) than in the 1999 (14.93 kg ha^{-1}) and virgin forest (8.9 kg ha^{-1}) catchments. The highest soil erosion value in the 2008 catchment was 338.18 kg ha^{-1} for 141.25 mm of rainfall.

3.3 Effects of forest management system on runoff and soil erosion

Selective logging and intensive line planting significantly increase direct runoff and soil erosion. The average direct runoff was 15.4% of rainfall in the virgin forest catchment, but 25.3% and 31.3% in the 1999 and 2008 catchments, respectively. The direct runoff rates in the 1999 and 2008 catchment were 2.05 and 2.22 times that of the virgin forest, respectively.

4. Conclusion and recommendations

TPTII significantly increase direct runoff and soil erosion. Forest land cover was a main factor determining the differences in runoff and soil erosion among the three catchments. Proper protection of the forest floor with plant cover under canopy trees would help control runoff and soil erosion.

We recommended controlling human erosional activities and combining ecologically based vegetation structure design and erosion control techniques for the effective control of runoff and soil erosion.

References

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