Rainforest Conversion Consequences on the Suspended Material Load and Output in the Nopu Catchment in Central Sulawesi, Indonesia

Rainforest Conversion Consequences on the Suspended Material Load and Output in the Nopu Catchment in Central Sulawesi, Indonesia

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Summary

Changes in suspended material load, soil erosion, water yield and nutrient concentration in the stream water due to the rainforest conversion were studied in the Nopu catchment of Central Sulawesi, Indonesia. The study area is characterized by steep slope of the terrain at the upper part followed by steep to gentle slope at the middle part and the floodplain was situated at the outlet of the catchment and the rainfall pattern is short but high in intensity causes rapid response of the discharge-hydrograph and sediment-graph. Forest conversion by smallholder farmers at the middle part of the catchment is still going on whereas at the upper part the natural forest remains undisturbed.

The general objective of this study is to investigate and quantify the effect of ongoing forest conversion on the suspended sediment load and output by employing the relationship between turbidity, discharge and the SSC as well as the other parameters such as soil erosion, runoff and nutrient concentration in a catchment scale. Therefore an upstream/downstream catchment design was chosen with complete instrumentations in the study area.

The result demonstrated the fact that there was an adverse impact of forest conversion on the suspended sediment yield as a result of the soil erosion and water yield by means of the annual runoff and the nutrient concentration in the study area. In spite of the rainfall amount was the main cause in generating the suspended sediment load in the stream water, the ongoing forest conversion accelerate the soil erosion and therefore increases in suspended sediment load entering the river. In comparison of the SSY in 2002 and 2004 at weir 2 (slash and burn sub-catchment) and weir 3 (natural forest sub-catchment), there was an increase of SSY by a ratio of 1.74 despite lower of yearly rainfall in 2004 in comparison to that of 2002. The plot scale of the soil erosion study emphasized this fact that most of the soil erosion and loss came from uncovered land and has a proportion of about 77% (or equal to 65,66 t ha^{-1}) of the total erosion rate in comparison to that from natural forest (0,57% or equal to 0,49 t ha^{-1}). Furthermore, an additional occasion such as landslide and bank

collapse along the steep slope of catchment's terrain altered the production of suspended sediment to the downstream part. Additionally, the water yield (annual runoff) also increased by the ratio of 1.41 in 2002 to 2.23 in 2004 (app. 200mm) in comparison of the runoff at weir 2 to that at weir 3, as a consequence of forest conversion. In terms of the nutrient concentration, the leaching effect of the surface runoff indicated that forest conversion also altered the nutrient availability particularly that from the slash and burn sub-catchment.

In the study area, a linear regression between the turbidity and the SSC was suitable with a better coefficient of determination in predicting the suspended sediment yield. Continuous turbidity measurement along with the continuous measurement of water level and the sampling of SSC make the prediction of the suspended sediment load possible and it can be used as an indicator for the complex soil erosion and sediment delivery processes in the catchment. Also the turbidity and water level data might be utilized in assessing the water quality, quantity and the variability for the water consumption purposes as well as the for the long term catchment monitoring of the impact of forest conversion.

Zusammenfassung

Auswirkungen der Regenwaldrodung in einem experimentellen Einzugsgebiet auf Zentralsulawesi in Indonesien (Nopu-Einzugsgebiet) wurden im Hinblick auf die Entwicklung von Bodenabtrag, Schwebstofffracht und Oberflächenabfluss untersucht. Das Untersuchungsgebiet am Rande des Nationalparks Lore Lindu ist gekennzeichnet durch steile obere Hanglagen, übergehend in mittlere Hangneigungen und einen flachen Schwemmfächer am Hangfuß am Auslaß des Einzugsgebietes. Tropisch ganzjährig konvektive Niederschläge mit teilweise hoher Intensität kennzeichnen die Niederschläge und verursachen eine schnelle Abflussreaktion mit höherer Sedimentführung über wenige Stunden. Seit 2000 tritt verstärkte Waldkonversion mit Brandrodung durch Kleinbauern im mittleren Einzugsgebiet auf, während das obere Teileinzugsgebiet naturnahen Regenwald aufweist.

Hauptziel der Arbeit ist die Quantifizierung der Auswirkungen der fortschreitenden Waldrodung auf den suspendierten Sedimentaustrag im Vergleich von naturnahem Regenwaldteileinzugsgebiet und in Konversion befindlichem mittleren Teileinzugsgebiet. Dazu wurden die Relationen zwischen Abfluss, Trübung und suspendierter Materialkonzentration im Vorfluter sowie Oberflächenabfluss und Bodenabtrag auf Erosionsparzellen am Hang über mehrere Jahre untersucht. Grundlage ist eine intensive Instrumentierung der Teileinzugsgebiete im Rahmen des SFB 552 seit Ende 2001.

Die Ergebnisse belegen den hohen Einfluss der Waldkonversion auf den Sedimentaustrag in Zusammenhang mit der Abflusserhöhung und verstärkter Bodenerosion auf kleinparzellierten Hangabschnitten. Niederschlagsmenge und –intensität generiert im gebirgigen Einzugsgebiet die kurzfristigen Hochwasserwellen mit erhöhter Schwebstoffkonzentration. Die Waldkonversion verursacht jedoch wenige, aber mit Bodenerosionsmaterial stark angereicherte Abflüsse pro Jahr. Ein Vergleich des Sedimentaustrages zwischen 2002 und 2004 am Wehr 2 (Brandrodungseinfluss) und Wehr 3 (naturnaher Regenwald) zeigt trotz geringerer

Jahresniederschläge in 2004 einen Anstieg mit dem Faktor 1,7 . Die Bodenabtragsplots bestätigen den großen Beitrag gerodeter Parzellen mit geringer Bodenbedeckung über einen kurzen Zeitraum für den Sedimenttransport ins Gerinne. Schwarzbrache (65,6 t/ha) und annuelle Kulturen liefern etwa 77% der gesamten Bodenerosion im Vergleich zu 0,6% (0,49 t/ha) der Regenwaldplots. Ferner tragen singuläre Erdrutsche und Ufererosion zur Sedimentbelastung bei. Als Folge der Waldkonversion nahm der Jahresabfluss in 2004 gegenüber 2002 um den Faktor 1,4 zu (+ 200 mm). Veränderungen der gelösten Nährstoffkonzentrationen im Vorfluter belegen einen erhöhten Auswaschungseffekt unmittelbar nach Brandrodung.

Im Untersuchungsgebiet ermöglicht eine gute lineare Regression zwischen Trübung und suspendierter Materialkonzentration die Verwendung des Trübungsparameters für die Abschätzung der Schwebstofffrachten. Kontinuierliche Trübungsmessungen in Verbindung mit den Abflussmessungen ermöglichen die Prognose des suspendierten Sedimentaustrages im Einzugsgebiet. Die Trübungs- und Abflussdaten ermöglichen ferner die Beurteilung von Wassermenge und Wasserqualität für die dörfliche Wassernutzung und sind für ein Langfristmonitoring des Einflusses der Waldkonversion in tropischen Kleineinzugsgebieten geeignet.

Intisari

Perubahan angkutan sedimen melayang, erosi tanah, yil debit serta konsentrasi unsur-unsur hara air sungai yang diakibatkan konversi hutan telah diteliti di daerah aliran sungai Nopu di Sulawesi Tengah, Indonesia. Daerah penelitian berkarakteristik curam pada daerah hulu DAS diikuti dengan curam sampai agak landai pada daerah tengah serta dataran banjir dapat dijumpai di daerah hilir sistim DAS dan pola hujan ditandai dengan waktu yang singkat namun berintensitas tinggi yang menyebabkan cepatnya aliran banjir dan sediment terjadi. Konversi hutan oleh para peladang di daerah tengah DAS tetap berlangsung sementara di bagian hulu DAS hutan asli masih tetap terjaga.

Tujuan umum penelitian ini adalah untuk meneliti dan mengukur pengaruh dari konversi hutan terhadap angkutan sedimen melayang dan hasil-hasilnya dengan menggunakan hubungan antara kekeruhan air, debit dan konsentrasi sedimen melayang pada skala daerah aliran sungai. Untuk itu dipilih pendekatan dan rancangan DAS hulu/hilir dengan instrumentasi yang lengkap pada daerah aliran sungai tersebut.

Hasil yang didapat membuktikan bahwa konversi hutan berdampak negatif terhadap yil sedimen melayang sebagai akibat dari laju erosi, yil debit yang dalam hal ini berupa limpasan tahunan dan konsentrasi unsur-unsur hara di daerah penelitian. Disamping curah hujan sebagai penyebab utama terjadinya angkutan sedimen melayang di sungai, konversi hutan yang masih berlangsung mempercepat laju erosi tanah sehingga meningkatkan angkutan sediment melayang yang masuk ke sungai. Dengan membandingkan yil sedimen melayang tahun 2002 dan 2004 pada bendung 2 (sub-DAS tebang dan bakar) dan bendung 3 (sub-DAS hutan asli), terdapat peningkatan yil sedimen melayang dengan perbandingan 1.74 walaupun pada tahun 2004 curah hujan tahunan lebih rendah dibandingkan tahun 2002. Skala plot studi terhadap erosi tanah (skala plot) mendukung fakta bahwa kebanyakan dari erosi tanah berasal dari lahan terbuka dengan kontribusi sekitar 77% (atau setara dengan 65.66 t ha^{-1}) dari total laju erosi dibandingkan dengan erosi dari hutan asli (0.57%

atau setara dengan 0.49 t ha^{-1}) dan kejadian tambahan seperti longsoran dan runtuhan tebing disepanjang daerah yang curam dari DAS menambah produksi sediment melayang pada daerah hilir. Disamping itu, yil debit (limpasan tahunan) juga meningkat dari perbandingan 1.41 pada tahun 2002 menjadi 2.23 pada tahun 2004 (setara dengan 220 mm) dengan membandingkan limpasan pada bendung 2 dengan limpasan pada bendung 3, sebagai akibat dari konversi hutan tersebut. Untuk konsentrasi sedimen, efek penyucian dari limpasan permukaan menandakan bahwa konversi hutan juga mempengaruhi ketersediaan hunsur hara utamanya pada sub DAS tebang dan bakar.

Di daerah studi, hubungan yang linier antara kekeruhan dan konsentrasi sedimen melayang paling cocok diterapkan dengan koefisien determinasi yang lebih baik dalam memperkirakan yil sedimen melayang. Pengukuran kekeruhan secara berkesinambungan bersamaan dengan pengukuran tinggi muka air dan pengambilan contoh konsentrasi sediment melayang memungkinkan perkiraan dinamika angkutan sedimen melayang dan perubahannya dan juga dapat diterapkan untuk memahami proses erosi yang rumit dan angkutan sedimen untuk cakupan DAS. Data kekeruhan dan tinggi muka air dapat pula digunakan didalam penilaian kualitas air, jumlah dan variabilitasnya untuk keperluan penggunaan air dan juga untuk pengawasan DAS berjangka panjang akibat konversi hutan, sampai keseimbangan baru tercapai.

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Abbreviations, Symbols and Conversion Units

Abbrev.	*Explanation*	*Unit*
a.s.l.	Above Sea Level	m
AWS	Automatic Water Station	-
AWS	Automatic Weather Station	-
c	Coefficient of Runoff	-
CHERP	Cikumutuk Hydrology and Erosion Research Project	-
DIN	Deutsche Industrie Norm	-
EIA	Environmental Investigation Agency	-
EPA	Environmental Protection Agency	-
FAO	Food and Agricultural Organization	-
FISP	Federal Interagency Sedimentation Project	-
FWI	Forest Watch Indonesia	-
GFW	Global Forest Watch	-
ICM	Integrated Catchment Management	-
ICP	Inductively Coupled Plasma-spectrometer	-
IM	Inorganic Material	-
IPB	*Institut Pertanian Bogor* (Bogor University of Agriculture)	-
ISO	International Organisation for Standardization	-
LLNP	Lore Lindu National Park	-
LÖ	*Landschaftsökologie* (Landscape Ecology)	-
NTU	Nephelometric Turbidity Unit	NTU
η	Porosity	%
OM	Organic Matter	-
ρb	Bulk Density	gr cm^{-3}
Q	Discharge or flow rate	m^3 sec^{-1}
SDM	Salt Dilution Method	-
SSC	Suspended Solid Concentration	g l^{-1}
SSL	Suspended Sediment Load	kg ha^{-1}
SSY	Suspended Sediment Yield	t ha^{-1} or t km^{-2}
Sta	Station	-
STORMA	Stability of Rainforest Margins in Indonesia	-
TNLL	*Taman Nasional Lore Lindu* (Lore Lindu National Park)	-
TSS	Total Suspended Sediment Sediment	kg or t
UNESCO	United Nations Educational, Scientific and Cultural Organization	-
USDA	United States Department of Agriculture	-
UTM	Universal Transverse Mercator	-
WRI	World Resources Institute	-
WWF	World Wide Fund	-

Chemical Conentrations

Ca	Calcium	mg l^{-1}
DC	Dissolved carbon	mg l^{-1}
DIC	Dissolved inorganic carbon	mg l^{-1}
DOC	Dissolved organic carbon	mg l^{-1}
K	Potassium	mg l^{-1}
Mg	Magnesium	mg l^{-1}
Na	Sodium	mg l^{-1}
N	Nitrogen	mg l^{-1}
C	Carbon	mg l^{-1}
NO_3	Nitrate	mg l^{-1}
NO_3-N	Nitrate N	mg l^{-1}
NH_4	Ammonium	mg l^{-1}
NH_4-N	Ammonium N	mg l^{-1}
P	Phosphorus	mg l^{-1}
Si	Silicon	mg l^{-1}
TC	Total Carbon	mg l^{-1}
TIC	Total Inorganic Carbon	mg l^{-1}
TOC	Total Organic Carbon	mg l^{-1}
TNb	Total bound of Nitrogen	mg l^{-1}

Units and Conversions

C^o	Degree Celsius
cm	centimeter
g	gram
ha	hectare
J	Joule
km	kilometer
l	litre
m	meter
mg	miligram
mm	milimeter
mS	mili-siemens
nm	nanometer
sec	second
W	Watt
µm	micrometer

1 p.p.m (part per million) = 1 mg l^{-1}
1 µm = 1/1000 mm
1m = 100 cm
1 ton = 1000 kg
t km^{-1} = $1*10^2$ t ha^{-1}