Overland flow and soil movement from forests in Kumaun Himalaya

D. C. Loshali, V. P. Upadhyay, and R. P. Singh
Department of Forestry, Kumaun University, Nainital 263002, India
AND
J. S. Singh
Department of Botany, Banaras Hindu University, Varanasi 221005, India

Received February 1, 1989
Accepted November 3, 1989

Loshali, D. C., Upadhyay, V. P., Singh, R.P., and Singh, J.S. 1990. Overland flow and soil movement from forests in Kumaun Himalaya. Can. J. For. Res. 20: 606–608.

Overland flow and soil movement were measured on small plots of three forest types in the Kumaun Himalaya. Average seasonal (June through September) overland flow (measured over 2 years) was 0.49% of the seasonal rainfall (1967 mm) and was always less than 1% of each rain event (there was less than 0.1% difference among forest types). Seasonal soil movement ranged from 2.3 to 3.2 $g \cdot m^{-2}$ among forest types and averaged 2.6 $g \cdot m^{-2}$. Both overland flow and soil movement were significantly different between months, being positively correlated with amount of rainfall. Sediment concentration of runoff water did not vary among months by more than 0.1 $g \cdot L^{-1}$. The study indicates that steep, forested slopes are not an important sediment source in Kumaun Himalaya.

Loshali, D. C., Upadhyay, V. P., Singh, R.P., et Singh, J.S. 1990. Overland flow and soil movement from forests in Kumaun Himalaya. Can. J. For. Res. 20 : 606–608.

L'écoulement de surface et le taux d'érosion du sol ont été mesurés dans trois places échantillons représentant trois types forestiers de Kumaun Himalaya. L'écoulement de surface moyen durant deux saisons, de juin à septembre, était de 0,49% de la précipitation totalisant 1967 mm, et n'a jamais dépassé 1% pour un événement pluvieux particulier (les différences entre les types forestiers étaient plus petites que 0,1%). Le taux d'érosion moyen était de 2,6 $g \cdot m^{-2}$ avec des valeurs variant entre 2,3 et 3,2 $g \cdot m^{-2}$ selon le type forestier. L'écoulement de surface et le taux d'érosion étaient positivement corrélés à la précipitation et significativement différents entre les mois. La variation de la concentration moyenne mensuelle des sédiments en suspension dans les ruisseaux n'a pas dépassé 0,1 $g \cdot L^{-1}$. Cette étude démontre que les pentes abruptes boisées ne sont pas une source importante de sédiments.

[Traduit par la revue]

Introduction

Forests in Himalaya play an important role in determining overland flow and soil losses. A considerable amount of rainwater is intercepted by the forest canopy, leaf litter, and ground vegetation. The remaining water either infiltrates the soil or becomes overland flow (Pathak et al. 1983, 1984; Pandey et al. 1983).

The rainfall pattern in the region is determined by the summer monsoon, which can exceed 2500 mm of rain. The annual flow of water from Himalaya to the plains is estimated at about 8.6×10^6 ha·m (Gupta 1983).

Deforestation and overexploitation of Himalayan forests have led to increased runoff and sediment load in the streams and rivers of northern India. Himalayan watersheds are reported to produce sediment yields of 16.4 to 921 $t \cdot km^{-2} \cdot year^{-1}$ (Gupta 1983). The present study estimates overland flow and soil movement in small plots of three representative forest types of Kumaun Himalaya.

Materials and methods

The study sites are located near Nainital (29°24′N, 79°28′E), with an elevation of 1600–1980 m. Soils on all plots are shallow, residual, sandy loams. The climate of the area is influenced by the monsoon pattern of rainfall. The year is divisible into three seasons: rainy or monsoon (June to September), winter (October to February), and summer (March to May). By elevation, the study area is located in a temperate belt, although latitudinally it falls within the subtropical belt. The influence of monsoon rainfall renders the climate different from that of a true temperate zone. Of the total annual rainfall (2500 mm), 86% occurs in the rainy season. Mean monthly temperature ranges from 4 to 26°C.

The study was conducted on three forest types (pine, mixed oak pine, and oak) located within a radius of 5 km. Characteristics of the study sites are given in Table 1.

Incident rainfall

At each site the incident rainfall was measured using a 12.5 cm diameter rain gage, and as well three 22 cm diameter buckets were placed away from the influence of tree canopy. Rainfall intensity of 669 showers was measured during the 2-year study.

Overland flow and soil movement

Three, 25-m^2 plots were installed on the representative slopes of each forest site. All four sides of the plot were delineated with metal plates sunk 15 cm into the soil, leaving 20 cm exposed. An outlet was left at the lower portion of the plot to release the runoff.

Surface runoff (overland flow) was collected in metal containers and filtered to separate sediment. The filter paper plus sediment was ovendried (at 80°C) to a constant weight. The weight of the sediment was determined. Collected runoff was measured and removed after each rain shower.

Results

Rainfall characteristics

Rainfall during the June through September monsoon season averaged 2230 and 1702 mm in 1985 and 1986, respectively. Among sites, average monthly rainfall for the 2 years varied by 17 mm or less, and for the 4 months it varied a maximum of 42 mm. Distribution of amount and intensity of rainfall was also uniform among sites. About 80% of rainfall events were <20 mm, and less than 2% were >100 mm (Table 2). Rainfall intensities ranged between 0.2 and 29.2 mm/30 min and averaged 3.2 mm/30 min. Rain-

Overland flow and soil movement from forests in Kumaun Himalaya

D. C. LOSHALI, V. P. UPADHYAY, AND R. P. SINGH
Department of Forestry, Kumaun University, Nainital 263002, India
AND
J. S. SINGH
Department of Botany, Banaras Hindu University, Varanasi 221005, India

Received February 1, 1989
Accepted November 3, 1989

LOSHALI, D. C., UPADHYAY, V. P., SINGH, R.P., and SINGH, J.S. 1990. Overland flow and soil movement from forests in Kumaun Himalaya. Can. J. For. Res. **20**: 606–608.

Overland flow and soil movement were measured on small plots of three forest types in the Kumaun Himalaya. Average seasonal (June through September) overland flow (measured over 2 years) was 0.49% of the seasonal rainfall (1967 mm) and was always less than 1% of each rain event (there was less than 0.1% difference among forest types). Seasonal soil movement ranged from 2.3 to 3.2 g·m^{-2} among forest types and averaged 2.6 g·m^{-2}. Both overland flow and soil movement were significantly different between months, being positively correlated with amount of rainfall. Sediment concentration of runoff water did not vary among months by more than 0.1 g·L^{-1}. The study indicates that steep, forested slopes are not an important sediment source in Kumaun Himalaya.

LOSHALI, D. C., UPADHYAY, V. P., SINGH, R.P., et SINGH, J.S. 1990. Overland flow and soil movement from forests in Kumaun Himalaya. Can. J. For. Res. **20** : 606–608.

L'écoulement de surface et le taux d'érosion du sol ont été mesurés dans trois places échantillons représentant trois types forestiers de Kumaun Himalaya. L'écoulement de surface moyen durant deux saisons, de juin à septembre, était de 0,49% de la précipitation totalisant 1967 mm, et n'a jamais dépassé 1% pour un événement pluvieux particulier (les différences entre les types forestiers étaient plus petites que 0,1%). Le taux d'érosion moyen était de 2,6 g·m^{-2} avec des valeurs variant entre 2,3 et 3,2 g·m^{-2} selon le type forestier. L'écoulement de surface et le taux d'érosion étaient positivement corrélés à la précipitation et significativement différents entre les mois. La variation de la concentration moyenne mensuelle des sédiments en suspension dans les ruisseaux n'a pas dépassé 0,1 g·L^{-1}. Cette étude démontre que les pentes abruptes boisées ne sont pas une source importante de sédiments.

[Traduit par la revue]

Introduction

Forests in Himalaya play an important role in determining overland flow and soil losses. A considerable amount of rainwater is intercepted by the forest canopy, leaf litter, and ground vegetation. The remaining water either infiltrates the soil or becomes overland flow (Pathak et al. 1983, 1984; Pandey et al. 1983).

The rainfall pattern in the region is determined by the summer monsoon, which can exceed 2500 mm of rain. The annual flow of water from Himalaya to the plains is estimated at about 8.6 × 10^6 ha·m (Gupta 1983).

Deforestation and overexploitation of Himalayan forests have led to increased runoff and sediment load in the streams and rivers of northern India. Himalayan watersheds are reported to produce sediment yields of 16.4 to 921 t·km^{-2}·year^{-1} (Gupta 1983). The present study estimates overland flow and soil movement in small plots of three representative forest types of Kumaun Himalaya.

Materials and methods

The study sites are located near Nainital (29°24′N, 79°28′E), with an elevation of 1600–1980 m. Soils on all plots are shallow, residual, sandy loams. The climate of the area is influenced by the monsoon pattern of rainfall. The year is divisible into three seasons: rainy or monsoon (June to September), winter (October to February), and summer (March to May). By elevation, the study area is located in a temperate belt, although latitudinally it falls within the subtropical belt. The influence of monsoon rainfall renders the climate different from that of a true temperate zone. Of the total annual rainfall (2500 mm), 86% occurs in the rainy season. Mean monthly temperature ranges from 4 to 26°C.

The study was conducted on three forest types (pine, mixed oak–pine, and oak) located within a radius of 5 km. Characteristics of the study sites are given in Table 1.

Incident rainfall

At each site the incident rainfall was measured using a 12.5 cm diameter rain gage, and as well three 22 cm diameter buckets were placed away from the influence of tree canopy. Rainfall intensity of 669 showers was measured during the 2 year study.

Overland flow and soil movement

Three, 25-m^2 plots were installed on the representative slopes of each forest site. All four sides of the plot were delineated with metal plates sunk 15 cm into the soil, leaving 20 cm exposed. An outlet was left at the lower portion of the plot to release the runoff.

Surface runoff (overland flow) was collected in metal containers and filtered to separate sediment. The filter paper plus sediment was ovendried (at 80°C) to a constant weight. The weight of the sediment was determined. Collected runoff was measured and removed after each rain shower.

Results

Rainfall characteristics

Rainfall during the June through September monsoon season averaged 2230 and 1702 mm in 1985 and 1986, respectively. Among sites, average monthly rainfall for the 2 years varied by 17 mm or less, and for the 4 months it varied a maximum of 42 mm. Distribution of amount and intensity of rainfall was also uniform among sites. About 80% of rainfall events were <20 mm, and less than 2% were >100 mm (Table 2). Rainfall intensities ranged between 0.2 and 29.2 mm/30 min and averaged 3.2 mm/30 min. Rain-

TABLE 1. Characteristics of the study sites

	Site		
	Khurpatal	Sariatal	Lands End
Dominant tree species	*P. roxburghii*	*P. roxburghii*, *Q. leucotrichophora*	*Q. leucotrichophora*
Elevation (m)	1600	1750	1980
Slope (degrees)	31.0	29.5	32.5
Tree density (stems/ha)	310	550	710
Tree basal cover ($m^2 \cdot ha^{-1}$)	12.7	28.8	27.7
% canopy cover	89.6	80.0	91.5
% ground cover	21.0	28.0	40.0
% fine soil content[a]	36.7	37.2	46.3

[a]Particles <0.2 mm.

TABLE 2. Average relative frequency of shower size and rainfall intensity classes (n = 669) in forested stands

Class	% frequency
Shower size (mm/shower)	
<20	80.3
20 to <40	10.8
40 to <60	4.0
60 to <80	2.3
80 to <100	1.0
≥100	1.6
Intensity (mm/30 min)	
<2	52.6
2 to <4	25.3
4 to <6	8.1
6 to <8	6.7
8 to <10	2.5
≥10	4.8

intensities were <4 mm/30 min for approximately 80% all storms, and less than 10% had intensities mm/30 min (Table 2).

rland flow

Overland flow was significantly influenced by the quan- of rainfall (p < 0.01). Monthly overland flow as a cent of rainfall for the 2 years of this study ranged from 5 to 0.60, 0.38 to 0.54, and 0.35 to 0.53% for pine, mixed –pine and oak forest, respectively. For all forests the sonal overland flow accounted for 0.49% of seasonal fall (Table 3). The maximum overland flow, expressed percent of incident rainfall, occurred during July of both s for all sites, but differences were less than 0.1%.

movement

he soil movement among the months and forest types, ed from 0.3 to 1.3 $g \cdot m^{-2}$. The largest total seasonal movement was in the pine forest (3.2 $g \cdot m^{-2}$), and lowest seasonal soil movement was in the oak forest $g \cdot m^{-2}$). On average, soil movement was 2.65 $g \cdot m^{-2}$ ble 3).

TABLE 3. Overland flow and soil movement in different months of the rainy season (average of 1985 and 1986)

	Rainfall (mm)	Overland flow		Soil movement	
		mm	%	$mg \cdot L^{-1}$	$g \cdot m^{-2}$
June	234	1.1	0.47	300	0.33
July	533	3.0	0.56	300	0.90
August	780	3.9	0.50	269	1.05
September	420	1.7	0.40	215	0.37
Total	1967	9.7	0.49	273	2.65

Discussion

Overland flow

Overland flow generally did not occur when rainfall was <5 mm. For all sites combined, overland flow was influenced by amount of rainfall according to the following regression

$$y = -0.4400 + 0.0058x$$

$$r^2 = 0.921,\ n = 24,\ S_{y.x} = 0.415$$

where y is overland flow (mm/month) and x is incident rainfall (mm/month).

With the advent of the rainy season, normally after the first fortnight of June, annual plants germinate and perennial plants sprout vigorously, resulting in the development of a ground cover that peaks during August. As a result, storms are more effective in producing overland flow in the earlier part of the rainy season.

Overland flow from all forest types accounted for only a small proportion of rainfall, always <1%. Low rainfall intensity and predominance of sand particles in the soil promotes infiltration. This agrees with the findings of Pathak et al. (1983, 1984) and Pandey et al. (1983) for other forest sites in Kumaun Himalaya. Pathak (1983) concluded that the major portion of rainwater infiltrates into the soil and then reoccurs in the channels, ravines, and land crevices. This distance of subsurface transfer may range from a few centimeters to several meters depending upon the soil texture, vegetation type, and rock structure of the area. Several investigators in other situations have reported that the hydrologic response to rain by a forested slope is dominated by the lateral downslope movement of water within the soil layers (Pierce 1967; Nutter and Hewlett 1971; Hornbeck 1973; Hewlett 1974; Bren and Turner 1979*a*) and that overland flow is a rare occurrence in forested watersheds (Freeze 1972; Waring et al. 1981). In such situations water can be transmitted laterally to channels as subsurface quick flow and can produce a typical hydrograph in the main stream (Pathak et al. 1984). Subsurface flow systems with shallow soil cover are especially susceptible to landslips and landslides in steep terrain. Singh et al. (1983) reported that landslides are a principal cause of sediment removal from Himalayan forests. Deforestation and other disturbances that potentially modify the subsurface hydrologic regime, such as road construction, need to be evaluated carefully for these types of systems (Bren and Turner 1979*b*).

Soil movement

At all sites, soil loss (y, $g \cdot m^{-2} \cdot month^{-1}$) was correlated with the amount of incident rainfall (x_1, $mm \cdot month^{-1}$) and overland flow (x_2, $L \cdot m^{-2} \cdot month^{-1}$) according to the following regressions

$$y = -0.0696 + 0.0015x_1 \qquad r^2 = 0.759,\ n = 24,\ S_{y.x} = 0.204$$

$$y = 0.0152 + 0.2681x_2 \qquad r^2 = 0.90,\ n = 24,\ S_{y.x} = 0.131$$

However, sediment concentration was not significantly correlated with overland flow volume. For example, soil loss was greatest in August and least in June, but sediment concentration in runoff was greatest (300 $mg \cdot L^{-1}$) in July and least (215 $mg \cdot L^{-1}$) in September (Table 3). The peak ground cover, in the later part of rainy season, thus reduces the sediment concentration in overland flow.

To conclude, the overland flow and soil movement from all three forest sites were similar and very low. The study indicates that steep slopes of the Himalaya are not an important sediment source, provided they are forested.

Acknowledgements

The study was funded by the Ministry of Environment and Forests, Government of India, New Delhi. We thank Dr. P.C. Pathak for helfpul suggestions.

BREN, L.J., and TURNER, A.K. 1979*a*. Overland flow on a steep, forested infiltrating slope. Aust. J. Soil Res. **17**: 43–52.

______ 1979*b*. The hydrologic output of small forested catchments: implications for management. Hydrological Water Resource Symposium, Institute of Engineers, Perth. Sept. 1979, Perth, Australia.

FREEZE, R.A. 1972. Role of subsurface flow in generating surface runoff. 2. Upstream source areas. Water Resour. Res. **8**: 1272–1283.

GUPTA, R.K. 1983. The living Himalayas. Vol. 1. Aspects of environment and resource ecology of Garhwal. Today and Tomorrow's printers, New Delhi.

HEWLETT, J.D. 1974. Comments on letters relating to Role of subsurface flow in generating surface runoff. 2. Upstream source areas by R.A. Freeze. Water Resour. Res. **10**: 505–606.

HORNBECK, J.W. 1973. Storm flow from hardwood-forested and cleared watersheds in New Hampshire. Water Resour. Res. **9**: 346–354.

NUTTER, W.L., and HEWLETT, J.D. 1971. Stream flow production from permeable upland basins. *In* Proceedings of the 3rd International Seminar for Hydrology Professors, 18–30 J 1971, West Lafayette, IN. UNESCO, Paris.

PANDEY, A.N., PATHAK, P.C., and SINGH, J.S. 1983. Water, sediment and nutrient movement in forested and non forested catchments in Kumaun Himalaya. For. Ecol. Manage. **7**: 19–29.

PATHAK, P.C. 1983. Vegetational hydrology and its impact on nutrient cycling in selected forest ecosystems of Kumaun Himalaya. Ph.D. thesis, Kumaun University, Nainital, India.

PATHAK, P.C., PANDEY, A.N., and SINGH, J.S. 1983. Partitioning of rainfall by certain forest stands in Kumaun Himalaya. Trop. Plant Sci. Res. **1**: 123–126.

______ 1984. Overland flow, sediment output and nutrient loss from certain forested sites in the Central Himalaya, India. J. Hydrol. **71**: 239–251.

PIERCE, R.S. 1967. Evidence of overland flow in forest watersheds. *In* International Symposium on Forest Hydrology: Proceedings, 29 Aug. – 10 Sept. 1965, Pennsylvania State University, University Park, PA. *Edited by* W.E. Sopper and H.W. Lull. Pergamon Press, Oxford, England. pp. 247–253.

SINGH, J.S., PANDEY, A.N., and PATHAK, P.C. 1983. A hypothesis to account for the major pathway of soil loss from Himalaya. Environ. Conserv. **10**: 343–345.

WARING, R.H., ROGERS, J.J., and SWANK, W.T. 1981. Water relations and hydrologic cycles. *In* Dynamic properties of forest ecosystems. *Edited by* D.E. Reichle. Int. Biol. Programme 23. pp. 205–264.