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NUTRIENT LOSSES IN PARTICULATE FORM AS WEIR POND SEDIMENTS FROM FOUR UNIT WATERSHEDS IN THE SOUTHERN APPALACHIANS

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ABSTRACT

Weir-pond sediments were collected at 3-month intervals for a period of 2 years from four watersheds with contrasting vegetation. Annual sediment losses for the four watersheds were 283 kg/ha from the coppice hardwoods, 176 kg/ha from the old field, 76 kg/ha from the pine plantation, and 30 kg/ha from the mature hardwoods. Greater losses occurred during the winter season. The composition of the sediments from the old field, coppice hardwoods, and pine plantation were similar (sand, 77.4%; silt, 13.6%; clay, 9.0%; and organic matter, 7.6%). By contrast, the values for the mature hardwoods were 49.9, 17.6, 32.5, and 21.9%. Nutrient concentrations varied from watershed to watershed and in some instances seasonally. The order of concentration from high to low was nitrogen, calcium, magnesium, potassium, sodium, and phosphorus. Nutrient loss as weir-pond sediments accounts for no more than 1% of the total loss.

Much has been written in the past decade of the effects of clear-cutting of small watersheds on water quantity and quality. Aubertin and Patric (1974) pointed out that water yield is increased following clear-cutting (approximately 4.5 per year per percent reduction in forest cover) and that with reforestation water yield is diminished. The effects of clear-cutting on water quality are not as straightforward and may be related in part to supplemental treatment accompanying the clear-cut. Following an experimental clear-cut with no harvest and a precut herbicide treatment to prevent revegetation, water quality was adversely affected (Hubbard Brook; Likens et al., 1967). A more conventional clear-cut was performed at Fernow, W. Va., simulating a more realistic silvicultural practice [merchantable timber and pulpwood harvested and remaining trees felled and left in place, thus permitting the establishment of an even-aged forest (Aubertin and Patric, 1974)]. Water yield was increased 20 cm the first year following the clear-cut and 6.4 cm the second year. Water quality was affected only slightly.

Brown, Gahler, and Marston (1973) monitored nutrient losses for 2 years in three small watersheds in the Oregon Coast Range prior to two logging treatments (patch cut and clear-cut–slash burned) and for 2 years following logging. No changes in concentration or yield were noted on the patch-cut watershed for nitrate nitrogen, phosphorus, or potassium. On the clear-cut–slash-burned watershed, nitrate nitrogen yield was increased from 4.94 to 15.66 kg/ha the first year following treatment. The data suggest a return to pretreatment levels within 6 years. Potassium concentration increased markedly with burning but returned to pretreatment level within 2 months. Concentration of phosphorus was unchanged. Similar treatment responses have been reported for the coast Douglas fir region by Fredriksen (1971).

The loss of nutrients from unit watersheds via the stream may be grossly categorized into (1) dissolved fraction, (2) suspended particulate fraction, and (3) erosional fraction that is rolled along the streambed. The concentrations and amounts of nutrients found in these fractions may be affected by land-management practices as is the actual weight of the erosional fraction (weir-pond sediment load).

There have been a number of clear-cut experiments of unit watersheds at the Coweeta Hydrologic Laboratory, Franklin, N. C., over the past 30 years. Posttreatment management has varied. The weight and nutrient losses in the erosional fraction from four watersheds, each under a different management practice, are given in this paper.

METHODS

Watershed 6 (old field, 8.86 ha) was clear-cut in 1958, and all merchantable timber was removed. It was then planted with Kentucky 31 fescue. In 1959, 6.7 metric tons of dolomitic limestone was applied to each hectare of the watershed along with 2.2 metric tons of 2–12–12 fertilizer. In 1966 the grass cover was killed with herbicides. No further treatment has been applied to the watershed since spring 1968. Watershed 13 (coppice, 16.11 ha) was clear-cut during 1939–1940. Sprouts were permitted to grow until 1962, when they were again cut. No treatment has been applied to the watershed since. Watershed 17 (white pine, 13.48 ha) was clear-cut in 1942, and annual sprout growth was cut most years until 1955. It was then planted with white pine in 1956. Watershed 18 (mature hardwood forest, 12.46 ha) serves as a control watershed. For a more detailed treatment history of these four watersheds see Johnson and Swank (1973).

Weir-pond sediments were collected at 3-month intervals for 2 years beginning in September 1969. The streams were sandbagged above the weir pond, and water was diverted over the weir. The water in the pond was siphoned, then the sediments were removed to plywood boxes. After a period of drainage, three samples of known volumes were collected and dried, and the weight was estimated. The samples were analyzed for particle size (Bouyouuos method), organic matter (ashing if >10% and potassium dicromate digestion if <10%), nitrogen (Kjeldahl), calcium, magnesium, potassium, phosphorus (Technicon Autoanalyzer), and sodium (atomic absorption). The percent sand, silt, and clay values reported were adjusted for the organic-matter content of the sediment.

RESULTS AND DISCUSSION

The organic and inorganic content of the weir-pond sediments are given in Table 1, along with the particle-size distribution of the inorganic fraction. The

TABLE 1

EROSIONAL LOSSES* (IN PARTICULATE FORM AS WEIR SEDIMENTS) FROM FOUR WATERSHEDS (SEPT. 69–SEPT. 70, 368 DAYS)† (SEPT. 70–SEPT. 71, 352 DAYS)‡

Watershed	Inorganic, kg/ha		Organic, kg/ha	Sand, %	Silt, %	Clay, %
	<2 mm	>2 mm				
Old field	16†	139.7	12.3	73.6 ± 1.6	15.2 ± 1.9	11.2 ± 0.5
(WS 6)	16‡	181.0	15.6			
Coppice	26†	242.5	15.5	80.2 ± 1.3	12.7 ± 1.0	7.1 ± 0.6
(WS 13)	31‡	266.0	17.0			
White pine	8†	74.0	7.0	78.5 ± 1.4	12.9 ± 0.8	8.6 ± 0.7
(WS 17)	6‡	64.9	6.1			
Mature hardwood	5†	26.9	7.2	49.9 ± 2.9	17.6 ± 1.2	32.5 ± 2.0
(WS 18)	2‡	26.6	7.4			

*Percentages represent averages of eight quarterly collections ±1 SE.
†Data taken September 1969 to September 1970, 368 days.
‡Data taken September 1970 to September 1971, 352 days.

sediment loss followed a general seasonal trend, with peak losses normally coming during the winter quarter. If we consider the old field watershed, coppice forest, pine plantation, and mature hardwood forest to form a general succession sequence, then it is clear that young successional stages have more erosion than older ones. The larger inorganic sediment loss from the coppice forest has two possible explanations: (1) longer stream channel and (2) part of the stream is underground, and erosion is enhanced by freeze–thaw action during the winter.

Sediment losses in the <2-mm fraction show good agreement for the 2 years. Annual losses of inorganic sediments (<2 mm) averaged 160.3 kg/ha from WS 6, 254.2 kg/ha from WS 13, 69.4 kg/ha from WS 17, and 26.7 kg/ha from WS 18. The larger sediment fraction (>2 mm) exhibited the same trend as the smaller fraction; however, its weight was generally 10-fold less. The annual rates of inorganic erosion (grams/hectare/day) were 483 (WS 6), 774 (WS 13), 209 (WS 17), and 83 (WS 18).

The amount of organic matter followed the same trend between the four watersheds as the inorganic fraction (Table 1); however, its percentage contribution to the weir-pond sediment did not. The percentages of organic matter in the sediments coming from the four watersheds were 8.1 (WS 6), 6.0 (WS 13), 8.6 (WS 17), and 21.0 (WS 18).

The composition of the sediments coming from the old field, coppice hardwood forest, and the pine-plantation watersheds was similar [averaging 77.4% sand, 13.6% silt, 9.0% clay, and 7.6% organic matter (Table 1)]. By contrast, the same values for the mature hardwood forest were 49.9, 17.6, 32.5, and 21.9%. The most obvious difference in the nonorganic sediment losses from the four watersheds other than amounts was the greatest proportion of clay and lesser amounts of sand coming from the hardwood forest.

The amount of inorganic sediments leaving the mature hardwood at Coweeta annually is higher than for a northern hardwood forest at Hubbard Brook (Bormann, Likens, and Eaton, 1969). The 2-year average of weir-pond sediments from the northern hardwood forest was 9.42 kg ha^{-1} water $year^{-1}$ as inorganics. The corresponding value for the hardwood forest at Coweeta was 30.25. Perhaps the main factors contributing to these differences are (1) the difference in slope; 26% at Hubbard Brook vs. 52% at Coweeta, (2) approximately 7 cm more precipitation per year at Coweeta, and (3) differences in soil characteristics. Organic losses were the same for the two systems; 7.8 kg ha^{-1} $year^{-1}$ at Hubbard Brook and 7.3 kg ha^{-1} $year^{-1}$ at Coweeta.

The concentration of calcium, magnesium, potassium, and phosphorus showed no regular seasonal pattern. In general, the concentrations were less in the sediments coming from the coppice forest; a fact probably related to the greater erosional losses. Nitrogen and sodium concentrations exhibited seasonal changes, with greatest concentrations occurring in the winter. For nitrogen this trend is undoubtedly related to the pattern of organic-matter losses, which was also higher during the winter months. No explanation can be made of the higher sodium concentrations during the winter.

The annual average concentrations of six elements are given in Table 2. There are several items worthy of notice. First is the consistently lower concentration of all elements in sediments from the coppice watershed. This fact is probably related to the larger erosional losses from the watershed. Second, the higher nitrogen concentrations in sediments coming from the hardwood-forest watershed are surely related to the higher organic matter losses. Third, the higher calcium and magnesium losses from the pine plantation and the hardwood forest are probably related to the large calcium and magnesium pool in the litter layer

TABLE 2

CONCENTRATION AND ANNUAL LOSS (<2-MM FRACTION) OF SELECTED ELEMENTS IN WEIR-POND SEDIMENTS FROM FOUR WATERSHEDS

Watershed	Phosphorus		Nitrogen		Sodium		Potassium		Calcium		Magnesium	
	ppm	kg/ha	ppm	kg/ha	ppm	kg/ha	ppm	kg/ha	ppm	kg/ha	ppm	kg/ha
Old field	9*	0.001	3077	0.49	24	0.004	60	0.009	977	0.15	143	0.02
(WS 6)	7†		3341		29		32		720		111	
Coppice	5*	0.001	1917	0.52	15	0.004	21	0.005	479	0.12	66	0.02
(WS 13)	4†		2275		30		18		497		57	
White pine	9*	0.001	2450	0.20	23	0.002	36	0.003	822	0.07	106	0.009
(WS 17)	7†		3066		37		30		887		89	
Mature hardwood	10*	0.000	6450	0.23	41	0.001	58	0.002	1883	0.06	170	0.005
(WS 18)	7†		8433		31		40		1127		140	

*Data taken from September 1969 to September 1970, 368 days.
†Data taken from September 1970 to September 1971, 352 days.

(Yount, this volume), and the high concentration of calcium and magnesium coming from the old-field watershed may be related to the dolomitic limestone application of 1959 (Best and Monk, this volume).

The adjusting concentration of nutrient loss to reflect total weight loss will give some idea of the importance of erosion on nutrient depletion of watersheds. The annual losses of the six elements are given in Table 2. The total losses are very small, actually less than 1% of the dissolved fraction (Johnson and Swank, 1973).

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