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Nutrient input and output in undisturbed and silviculturally treated tropical rain forest in Suriname

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Abstract

Nutrient inputs and outputs in a catchment area with undisturbed forest were compared with those in a catchment area with silviculturally treated forest in Suriname. Treatment was according to the Celos Silvicultural System. Research was aimed to test the sustainability of this system on poor tropical soils. Treatment slightly increased nutrient outflow by creek water, but even in the treated area nutrient outflow was still smaller than nutrient inflow by rain water.

Keywords: nutrients, rain forest, conservation, Suriname, catchment, silviculture, tropical hardwoods

Introduction

To save the tropical rain forests two approaches are possible: a conservationist approach and an economic approach. The former is proclaimed loudly nowadays: make large reserves of remaining forest areas, forbid clearing for agriculture and cattle ranging, and ban imports of tropical hardwoods in e.g. Europe.

The economic approach could also help to conserve part of the tropical rain forests. Natural forests could be used for the production of tropical hardwoods and other forest products on a sustainable basis. By giving the natural forest an economic value, forestry land use might be able to compete economically with other activities on the poorer soils. On good soils this is normally not possible.

Over extensive areas in the tropics, soils are of reasonable physical quality but they are extremely poor in nutrients and in nutrient holding capacity. In such areas timber production by the natural forest might be a viable land use option. In these chemically poor soils, forests can maintain themselves by keeping most nutrients in the living and dead organic matter and by cycling them tightly in an almost closed cycle. Any leakage will soon lead to nutrient deficiencies if it is not compensated for by nutrient inputs.

An important aim of the forestry research in Suriname was to study the possibilities to increase the production of tropical hardwoods in the natural forest by an alternation of controlled exploitation and silvicultural treatment in a sustained system (Boxman et al., 1985).

The Celos Silvicultural System (CSS), developed in Suriname, is a polycyclic management system to produce tropical hardwoods with selective harvests every 20 to 25 years (de Graaf, 1986; Jonkers, 1987). Harvest operations are carefully planned to reduce skidding costs and to keep damage to the residual stand at a modest level, while creating sufficient gaps where regeneration of commercial valuable species can develop. Growth of commercial trees is stimulated by killing competing lianas and trees without market potential (refinements). Tropical hardwood produced in such a sustained way is expected to be welcomed in conservation-minded countries. The complete range of original plant and animal species of the natural forest ecosystem is kept largely intact. Such silvicultural system might help to save tropical forests from the present widespread destruction.

The sustainability of CSS with respect to nutrients was studied by measuring and comparing nutrient inputs and outputs in an undisturbed forest area and in an area with forest that was treated according to the CSS system. The killing of a substantial part of the biomass during treatment results in increased organic matter decomposition and related nutrient mineralization, which in turn might cause an increase in outflow of nutrients, a lowering of nutrient capital, and therefore site degradation.

This danger of nutrient leaching is especially strong during the first years after treatment when the fine litter decomposes. Wood decomposition proceeds much slower and will initially even lead to immobilization of nutrients.

Materials and methods

An area covered with mesophytic tropical rain forest was used in this experiment. The area was the same as the experimental basin described in the paper on forest hydrology (Poels, 1989).

Cycling of nutrients was studied in two catchment areas of about 150 ha each. The forest in one catchment was left undisturbed and in the other catchment the forest was treated according to the Celos Silvicultural System. This treatment consisted of an exploitation of about 20 m^3 stemwood per ha, followed by a refinement in which about 40 % of the biomass was killed.

Biomass amounts and nutrient cycling were studied for both catchments to estimate the changes in amounts and fluxes that occurred as a result of silvicultural treatment. Amounts of phytomass and litter and their composition were determined. Two nutrient cycles were distinguished: nutrients in the organic matter cycle (phytomass, litter, soil organic matter) and nutrients in the hydrological cycle (rain, soil moisture, groundwater, creek water).

Results and discussion

Undisturbed forest had a living phytomass of about 540 t ha^{-1} (dry weight). This amount decreased to about 310 t ha^{-1} one year after refinement, resulting in a sharp increase in litter amount and organic matter decomposition. In a period of 3 years after treatment practically all additional fine litter (leaves and twigs) and about 40 % of the additional coarse woody litter was decomposed.

The nutrient release from additional decomposition of organic matter as a result of treatment was calculated using as decomposition rates for fine litter (leaves and twigs), medium litter (wood <3 cm diameter) and coarse litter (wood >3 cm diameter), 2, 0.5 and 0.2 year^{-1}, respectively. That means that for instance of coarse woody litter every year 20 % decomposes. This calculated release (during the 3-year period after harvest) was: 150 kg N, 900 kg Ca, 70 kg Mg, 400 kg K and 30 kg P per ha. Potassium, being present in the litter but not incorporated in organic molecules, was probably released faster and in somewhat larger amounts than indicated. The same holds for part of the Ca and Mg. Very little, however, of these nutrients was discharged through the creek: the extra outflow in creek water during the same period from the treated area (as compared to the outflow from the untreated area) was 2 kg N, 8 kg Ca, 2 kg Mg, 4 kg K and 0 kg P per ha, or about only 1 % of the extra release.

Where did these nutrients go? They didn't go to the upper soil layers (0-120 cm) and not to the upper groundwater layers, since soil and groundwater samples of treated and untreated areas did not differ. Extra nutrient supply could have led to increased uptake by the remaining vegetation. Other possibilities are enrichment of deeper soil and groundwater layers and of soil and vegetation of footslopes and valley bottoms where groundwater reappears after its flow through solum and substratum.

Nutrient inflow by rain water and nutrient outflow by creek water were compared, average rainfall and discharge amounting to 2143 and 514 mm year^{-1}, respectively. In a catchment with a climax vegetation and some release of growth limiting nutrients by weathering, a slightly larger outflow of such nutrients by creek water than inflow by rain water might be expected. In the study area this was not the case (Table 1).

Table 1 (fluxes) shows that for most nutrients (Ca, N, P, K, S) the inflow by rain water was actually larger than the outflow by creek water. Of these, Ca, P and K might be accumulating, N and S are unsure because of gaseous exchanges with the

Table 1. Average concentrations of water samples (mg l^{-1}) and fluxes of some elements (kg ha^{-1} year^{-1}) for undisturbed (1) and treated areas (2).

	Ca	Mg	N	P	K	Na	Cl	S	Si
Average concentration (mg l^{-1})									
Rain	0.74	0.12	0.88	0.037	0.64	0.44	0.87	0.30	0.25
Discharge 1	1.49	0.87	0.03	0.033	0.50	3.91	3.85	0.30	5.63
Discharge 2	1.99	0.95	0.14	0.035	0.61	4.52	4.11	0.28	6.98
Flux (kg ha^{-1} yr^{-1})									
Rain	15.9	2.6	18.8	0.8	13.7	9.4	18.6	6.4	5.4
Discharge 1	7.7	4.5	0.2	0.2	2.6	20.1	19.8	1.5	28.9
Discharge 2	10.2	4.9	0.7	0.2	3.1	23.2	21.1	1.4	35.9

atmosphere. For Mg, Na and Si there was a net outflow, probably caused by weathering of minerals that contain these elements. For Cl inflow and outflow are in balance. Discharges of nutrients are larger in the treated area but still smaller than inflows with rain water. The large water use of the forest reduces the losses by outflow and hence makes accumulation of nutrients possible. Considering the current nutrient amounts, it is not likely that accumulation has proceeded at present day levels for many thousands of years. Probably rather recently (a few centuries ago) the forest has been destroyed or disturbed due to e.g. large storms, large fires or Amerindian occupation. Also nutrient amounts in rainfall might be somewhat higher nowadays than before because of human activities (deforestation, industrialization) or volcanism.

Conclusion

In the studied natural forests on loamy Zanderij soils in Suriname the inflow of nutrients with rain water is larger than the outflow with creek water. In treated forest the outflow of nutrients is larger than in undisturbed forest but still smaller than the inflow by rain water.

It is concluded that silvicultural treatment according to the CELOS system will not lead to appreciable losses of nutrients from the ecosystem and that forestry according to this system can be considered sustainable from a nutrient point of view.

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