INTERNAL REPORT 111

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Models Relating to Terrestrial Mineral Cycling - Progress Report

ABSTRACT

Although no formal project in mineral cycling was defined for 1972, three modeling efforts were begun: calcium cycling at Cedar River, litter decomposition, and miombo ecosystem. The calcium cycling model is a simple compartment model and was developed as a practice exercise. It demonstrates the inadequacy of linear-donor control formulation for describing the transfer of a non-limiting nutrient. The litter decomposition model is used to examine the processes related to the incorporation of organic material into the soil horizons. It is a nonlinear model using difference equations on a one-week time resolution. It has not yet been coupled to mineral release. The miombo ecosystem model follows the flux of carbon through a central African ecosystem. It demonstrates the seasonal changes in biomass in various vegetation and animal components.

In addition to the assigned modeling projects, several additional projects were undertaken, when the need for modeling help arose. Substantial time and energy were spent on three such projects in 1972: calcium cycling at Cedar River, litter decomposition, and the miombo ecosystem. The former two models were begun in anticipation of further modeling of nutrient exchange in 1973 and to aid the biogeochemical cycling committee in gaining a modeling perspective. The model of the miombo was done as a part of the Woodlands Workshop held in Oak Ridge, Tennessee in August 1972.

Calcium cycling at Cedar River

This model (Fig. 1) was done as a practice exercise in model conceptualization. It was used to demonstrate the consequences of model assumptions on a simple compartment model. Four versions of this model were investigated (Table 1). The data used in generating these models came from the Cedar River intensive site (Grier and Cole 1972). In the first two versions, a constant coefficient, linear donor control scheme was used to describe calcium fluxes and the data from 1965 and 1971 were used, respectively. In the third version the flux coefficients in the donor control scheme were linearly related to time. The fourth version utilizes a donor-receiver control formulation and a logistic curve for the forcing function.

In the first two versions, stable calcium capitals are reached (Table 2). In the third version, the calcium capitals do not stabilize. Analytical solution for the stable values for version 4 has not been found. Further analysis of these formulations is planned in 1973.

These exercises form the preliminary step in the investigation of modeling schemes for examining nutrient cycling at a coarse level of resolution. After further investigation, these models will be presented as a biome internal report and at a workshop meeting of the biogeochemical committee.

Litter decomposition model:

This model was conceptualized late in the year and is currently being tested. It will be presented in detail at the Northwest Science Association meetings at Walla Walla, Washington in March 1973 so only a brief sketch will be given here.

The model follows weight changes in four components of the litter layer and soil on a weekly time resolution (Fig. 2). Estimates of initial values of the state variables, precipitation and temperature schedules come from data taken at the Cedar River intensive site.

The compartments of the model are defined as follows:

Woody litter - dead branches, boles, and woody reproductive parts and associated microflora and fauna found in the forest floor.

nonwoody litter - dead small twigs, needles, leaves, and other nonwoody, or small sized material and associated microflora and fauna found in the forest floor.

Organic soil horizon - partially incorporated organic matter, dead roots and associated microflora and fauna found in the FSH, and A1 soil horizon.

Mineral soil horizon-incorporated organic matter, dead roots and associated microflora and fauna found below the A1 soil horizon.

The main assumption in this model is that there is no net annual change in the weight of these compartments, but there are seasonal changes. It is the purpose of this modeling effort to investigate the range of transfer rates that comply with this assumption. Difference equations are used as the state equations and the transfer rates are non-linear functions of the donor or receiver compartment values and environmental variables.

A complete discussion of the results of this model will be published as a biome internal report. This project was designed as a preliminary step to formulating a mineralization model.

The miombo ecosystem model

This modeling exercise was done in conjunction with Dr. Francois Malaisse of the Universite Nationale du Zaire.

The model describes the seasonal variation in biomass in the miombo ecosystem of Central Africa. The incoming energy is partitioned between overstory trees and the ground cover community. The model structure is diagrammed in Fig. 2. The seasonal dynamics are characterized by one rainy season (November to March) and one dry season (May to September). It was assumed that the system is in a state of equilibrium with respect to the yearly apportionment of biomass. For this reason, the model was initially constructed as a balanced linear-donor control model. Parameter values were derived from data given in a paper by Malaisse _et al_. (1972) and from his unpublished research. Time varying forcing functions were added to give the seasonal patterns.

The model generally simulated the expected seasonal biomass distributions. Further work on this model is planned and Dr. Malaisse is currently gathering information concerning the influence of fire on biomass distribution. We hope to incorporate this into an expanded version of the model reported here.

Expected publications

Internal reports:

Calcium cycling model for Cedar River

Miombo ecosystem model

Formal publications

A model of litter decomposition in a coniferous forest (to be submitted to Northwest Science).

Literature cited:

Grier, C. C. and D. W. Cole. 1972. Elemental transport changes occurring during development of a second-growth Douglas-fir ecosystem. In: J. F. Franklin, L. J. Dempster, and R. H. Waring (eds.), Proceedings - research on coniferous forest ecosystems - a symposium, p. 103-113. Pac. Northwest Forest and Range Exp. Stn., Portland, Oreg.

Malaisse, F., J. Alexandre, R. Freson, G. Goffinet, and M. Malaisse-Mousset. 1972. The miombo ecosystem: a preliminary study. In: P. M. Golley and F. B. Golley (eds.), Tropical ecology with an emphasis on organic productivity, p. 363-405. University of Georgia, Institute of Ecology. Athens, Georgia.

Table 1. Four formulations of the calcium cycling model for Cedar River intensive site.

Version	State equations
1	$\dot{x}_1 = 0.022x_3 + 0.055x_2 - 0.053x_1$
	$\dot{x}_2 = 0.28 + 0.053x_1 + 0.009x_3 - 0.174x_2$
	$\dot{x}_3 = 1.05 + 0.119x_2 - 0.037x_3$
2	$\dot{x}_1 = 0.020x_3 + 0.067x_2 - 0.128x_1$
	$\dot{x}_2 = 0.93 + 0.128x_1 + .008x_3 - 0.381x_2$
	$\dot{x}_3 = 0.61 + 0.315x_2 - 0.039x_3$
3	$\dot{x}_1 = (0.055 + 0.002t)x_2 + (0.022 - .0003t)x_3 - (0.053 + 0.012t)x_1$
	$\dot{x}_2 = 0.28 + 0.108t + (0.053 + 0.012t)x_1 + (0.009 - .001t)x_3 - (0.174 + 0.034t)x_2$
	$\dot{x}_3 = 1.05 - 0.073t + (0.119 + 0.032t)x_2 - (0.038 - .001t)x_3$
4	$\dot{x}_2 = 0.144x_4 + 0.030x_5 + 0.027x_6 + 0.009x_3 - 0.119x_2 - \frac{0.038x_2x_6}{x_2+x_6} - \frac{0.028x_2x_5}{x_2+x_5} - \frac{0.090x_4x_2}{x_4+x_2} + \left(\frac{1}{1+2.93e^{-.615t}}\right)$
	$\dot{x}_3 = 0.119x_2 + 1.05 - 0.006t - 0.009x_3 - \frac{0.049x_3x_6}{x_3+x_6} - \frac{0.044x_5x_3}{x_5+x_3} - \frac{0.131x_4x_3}{x_4+x_3}$

Table 1. (Cont.)

Version	State equations
	$\dot{x}_4 = 0.090\dfrac{x_4 x_2}{x_4+x_2} + 0.131\dfrac{x_4 x_3}{x_4+x_3} - 0.144x_4$
	$\dot{x}_5 = 0.028\dfrac{x_2 x_5}{x_2+x_5} + 0.044\dfrac{x_5 x_3}{x_5+x_3} - 0.030x_5$
	$\dot{x}_6 = 0.038\dfrac{x_2 x_6}{x_2+x_6} + 0.049\dfrac{x_6 x_3}{x_6+x_3} - 0.027x_6$

where:

x_1 = calcium content of canopy including bole

x_2 = calcium content of forest floor

x_3 = calcium content of rooting zone

x_4 = calcium content of leaves

x_5 = calcium content of branches

x_6 = calcium content of boles

Table 2. The initial conditions and stable values for the compartments in the calcium cycling model. Version 1 is based on 1965 data and version 2 is based on 1971 data (in grams per square meter).

	Version 1		Version 2	
	Initial Condition	Stable Value	Initial Condition	Stable Value
Canopy	29.6	115.7	33	11.43
Forest Floor	14.6	44.0	12.3	5.1
Rooting Zone	74.0	166.7	82.0	55.4

Figure 1a. A diagram of the compartment model of calcium cycling at Cedar River for the first three versions of the model.

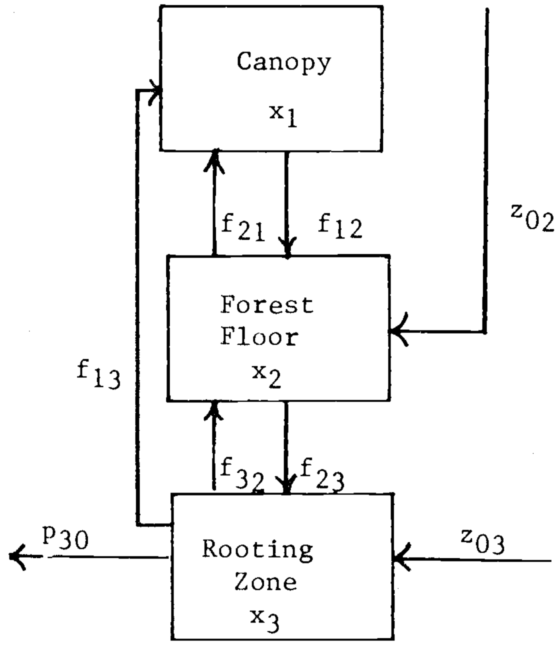

Figure 1b. A diagram of the fourth version of the calcium cycling compartment model.

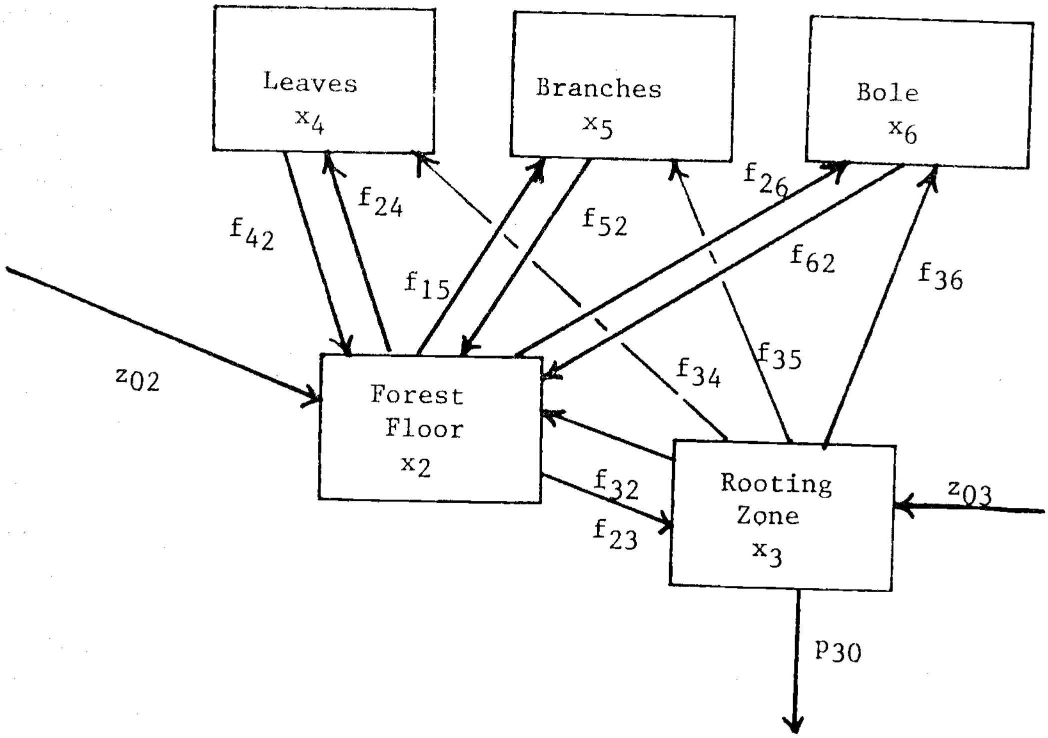

Figure 2. A diagram of the litter decomposition model.

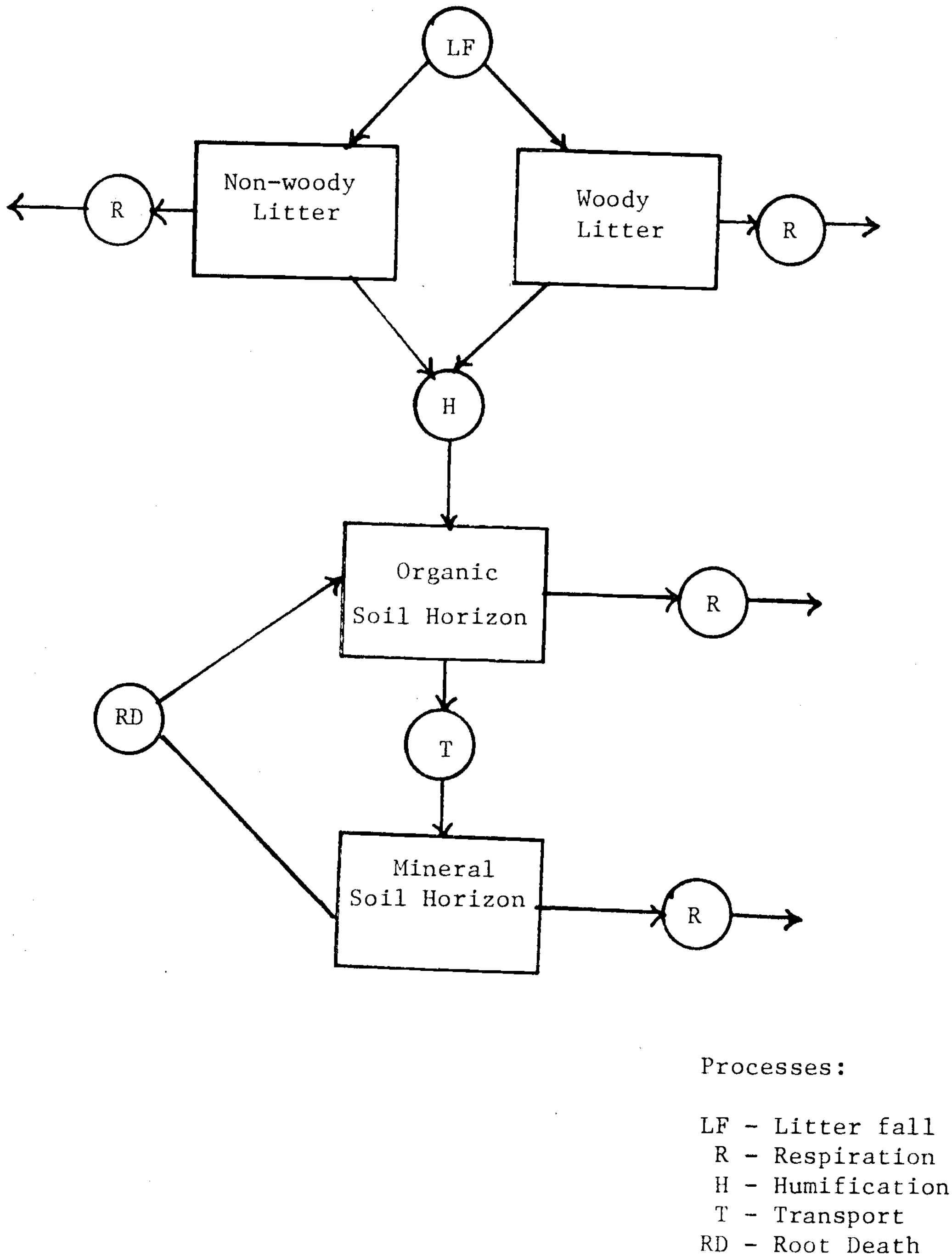

Figure 3. A diagram of the compartment model of the miombo ecosystem.