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A GRAZING LANDS PLANT-DECOMPOSITION, CARBON-MINERAL SIMULATION MODEL

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ABSTRACT

A relatively low resolution nonlinear carbon flow and nutrient cycling model has been developed for use in international comparison of primary production and decomposition in grazing lands ecosystems. The plant state variables are live green, above- and belowground reserves, and roots for each of the plant groups including shrubs, perennials, annuals, and cryptogams.

The producer carbon submodel is divided into three parts: assimilation, translocation, and death. The functions are dependent on radiation, temperature, soil water, and the amount of biomass. Site specific sine wave curves are used to describe radiation and air and soil temperatures, while soil water is described as a piecewise function with time. The soil parameters are described for three soil layers, determined by root biomass in the various depths.

The decomposition submodel is a carbon flow model. The biomass of herbaceous and woody litter and dead belowground parts as well as dead cryptogams are separated into "easy," "medium," and "difficult" decomposed factions. A constant maximum decomposition rate is used for each faction, modified by environmental factors.

The nutrient submodel is made dependent on carbon flows both in the producer carbon submodel and the decomposition submodel. Similar diagrams are used for various nutrients, having an "unavailable" pool of nutrients in the soil. Nutrients available to the plants are slowly released from this to various layers in the soil. The nutrients may be taken up by roots or leached down in the soil. For nitrogen it was found necessary to include the possibility for nitrogen fixation in addition to the general pathway.

The model has been tried for a lichen heath and a perennial grassland site and has given reasonable output.

INTRODUCTION

A simulation model can be built for a total ecosystem as, for example, the ELM model of the IBP Grassland Biome (Anway et al., 1972) and the preliminary U.S. Tundra model (Timin et al., 1972), or could cover a subsection of the total system such as in the simulation of a photosynthetic system (e.g., de Wit, Brouwer, and Penning de Vries, 1970) or a plant-mineral uptake system (Miller, 1972), or decomposition (Bunnell, 1972). Usually a model working on a part of the total system is also very detailed. This might mean that the model is biologically more realistic because it is possible to base it on physiological response. On the other hand, total ecosystems models are, for reasons of balance, less detailed across their range of consideration, and in the case where their application is site to site comparisons, the appropriate level of detail becomes even lower.

The aim of this paper is to introduce a relatively low resolution general simulation model for grazing land ecosystems. The model is designed to handle a wide range of situations and to be useful from relatively humid to dry ecosystems and from cold (arctic and alpine tundra) to warm areas of the globe--a range of conditions covered by IBP sites. Although animals are important factors of the ecosystems, they are not included in the present model.

The model is based on the producer model from the International Grassland/Tundra Workshop held in early fall 1972 (Wielgolaski, 1972), and some of the ideas are similar to this. The time scale used in the present model, as in the workshop model, is 1 day. The model utilizes the simulation compiler developed at the U.S. IBP Grassland Biome. A revised version (SIMCOMP IV) of the compiler described by Gustafson and Innis (1972*a*,*b*) has been used.

ABIOTIC SUBMODEL

Daily radiation and air temperature based on yearly sine curves with site-specific amplitudes (ARMAX-ARMIN and ATMX-ATMN, respectively) were used as driving variables. It was, however, necessary to introduce a site-specific time lag for temperature (ATLAG) in relation to radiation, as in many places maximum and minimum temperatures occur somewhat later than the radiation extremes. It was also necessary to introduce site-specific soil temperature sine curves for the three soil layers studied with specific temperature amplitudes (ATSMX and ATSMN) and site-specific time lags in relation to air temperature (ASLAG1, ..., ASLAG3). The three soil layers (ASP1, ..., ASP3) are relative values of the total soil depth (mm) of interest (ASODP). The relative depths of each of the layers are site-specific, dependent on the proportional root distribution in the soil.

Site water relations are modelled by simulated time trends in soil water contents and not by considering precipitation patterns and soil water budgets. The water conditions at the sites are defined by the soil water contents in three soil layers and by site-specific maximum and minimum volumetric soil water content (ASMAX, ASMIN) and the volumetric water content at wilting point (ASWP) and at field capacity (ASFC). Water contents of each layer vary through the year by a piecewise linear function from 0 (at ASMIN) to 1 (at ASMAX) defined by four time parameters (ATS1, ..., ATS4) for each of the three soil layers (see Fig. 1).

ATS1 = time when soil water begins to increase from the minimum value

ATS2 = time for lower limit of optimal soil water range

ATS3 = time for upper limit of optimal soil water range

ATS4 = time when soil water is at a minimum again

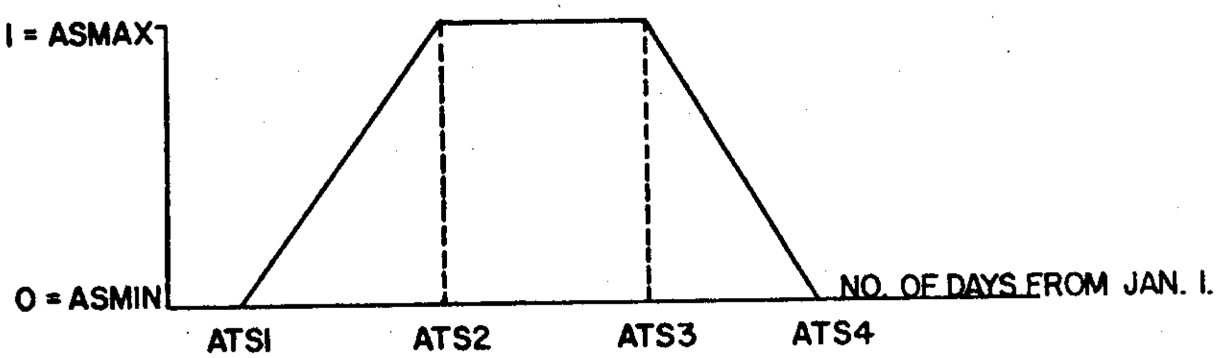


Fig. 1.

CARBON SUBMODEL

Four carbon compartments (live green, aboveground reserves, belowground reserves, and live roots) are considered for each of four plant types (shrubs, perennial herbs, annual herbs, and cryptogams). The flows between compartments, the atmospheric source/sink for carbon, and the location of the controls are shown in Fig. 2. The numbering of the 16 producer carbon state variables (X_{21-36}) is as shown in Fig. 2. In the nitrogen submodel (see later section) a subdivision of each of the four plant types is made whereby a proportion of the plant type is considered to have nitrogen fixing capacity.

Extension of the model would most likely require further subdivision of these compartments to allow for the separate treatment of grasses, other monocotyledones and dicotyledones for the annual and perennial herb categories, bryophytes and lichens for cryptogams, cool-season and warm-season plants within all groups, and similarity for leguminous and nonleguminous nitrogen fixers. The level of the present treatment was dictated by the time available for the project and also by the fact that this was to be an extension of the International Grassland/Tundra Workshop.

Perhaps the biggest shortcoming of the present model is that it does not allow competitive interrelations to modify the carbon balance of plant types

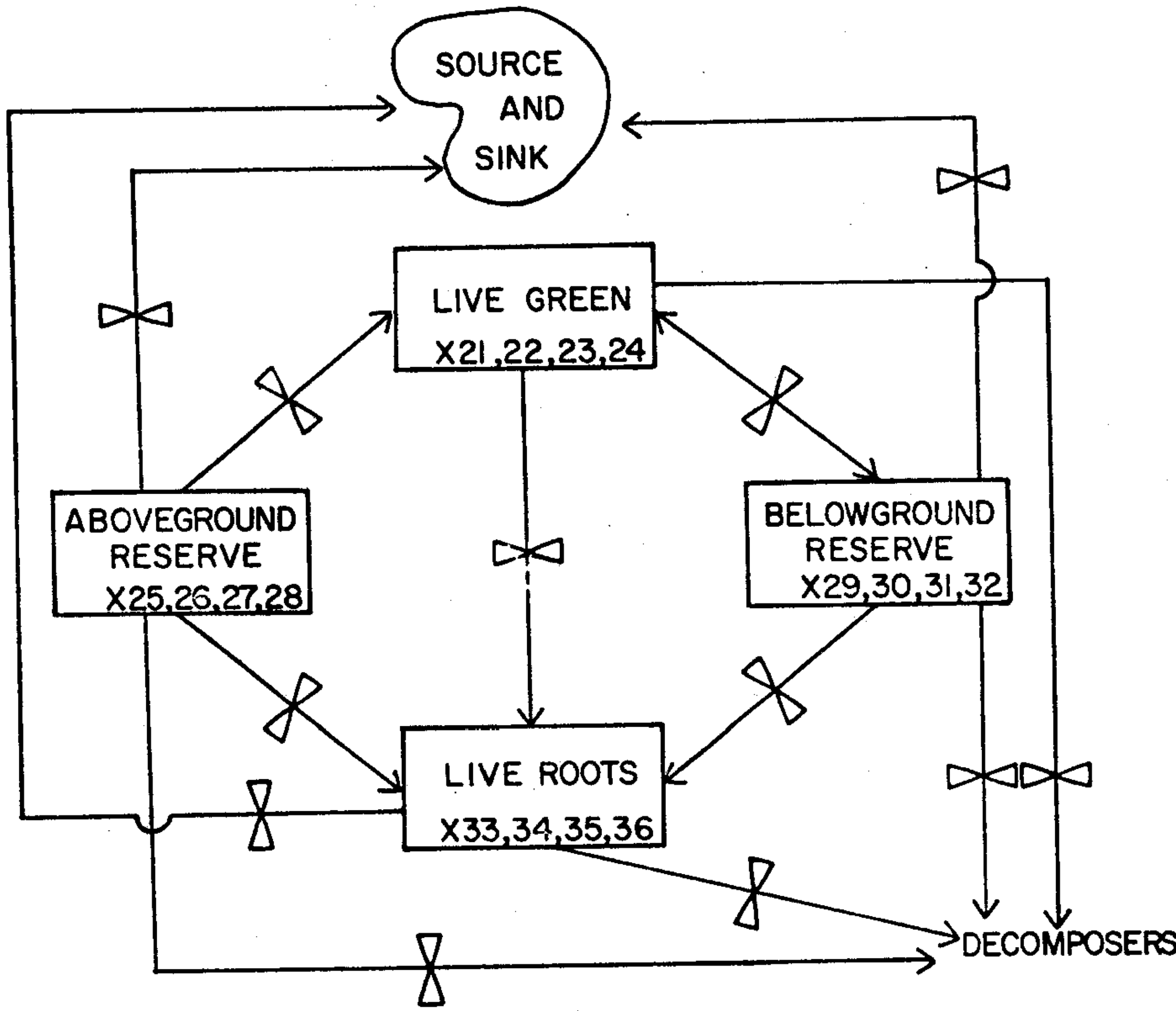


Fig. 2. Elementary diagram of the producer subsystem.
X21,25,29,33 are state variables for shrubs.
X22,26,30,34 are state variables for perennial herbs.
X23,27,31,35 are state variables for annual herbs.
X24,28,32,36 are state variables for cryptogams.

growing together. Each of the four plant types operate independently so that the only way in which the response of a complex community can be approximated is by addition of the individual response of the component plant types.

Functional Description

It was decided during the workshop that all inputs into the producer system were flowing through *live green biomass*, resulting in an increase in this state variable and/or translocation to *reserves* (above- and belowground) and to *live roots*. By definition translocation from reserves to live green biomass or to roots is possible. The outputs from the system are the amount of dead material from all state variables and respiration from live roots and reserves. Respiration of live green is not treated separately during the growing season. When assimilation is higher than respiration the net flow into live green is calculated. The function for breakdown of the plant material is discussed in the decomposition section.

Net Assimilation

Net assimilation (NA) is defined as the net gain of CO_2 from the atmospheric source/sink to green biomass. It is expressed in g dry weight/m^2/day.

Assumptions:

1. NA is a function of air temperature, soil water, radiation, and the amount of green biomass:

$$NA = f(T, W, R, X_{21-24})$$

where f = function, T = temperature, W = water content of soil, R = radiation, X_{21-24} = biomass of green parts of shrubs, perennial herbs, annual herbs, and cryptogams, respectively. The explicit form of this function is:

$$NA = PMGR \cdot PFT \cdot PFW \cdot PFR \cdot PFS \cdot X_{21-24}$$

where PMGR = maximum relative growth rate (g/g/day) when conditions for growth are optimal. PFT, PFW, PFR, and PFS are factors varying between 0 and 1 and expressing the effects on the relative growth rate of temperature, soil water, radiation, and self shading, respectively.

2. The response of NA to temperature (T) is a piecewise linear function defined by four parameters (see Fig. 3).

PTMN = minumum air temperature compensation point in °C

PTØ1 = lower limit of the optimal air temperature range in °C

PTØ2 = upper limit of the optimal air temperature range in °C

PTMX = maximum air temperature compensation point in °C

T = air temperature at the given moment

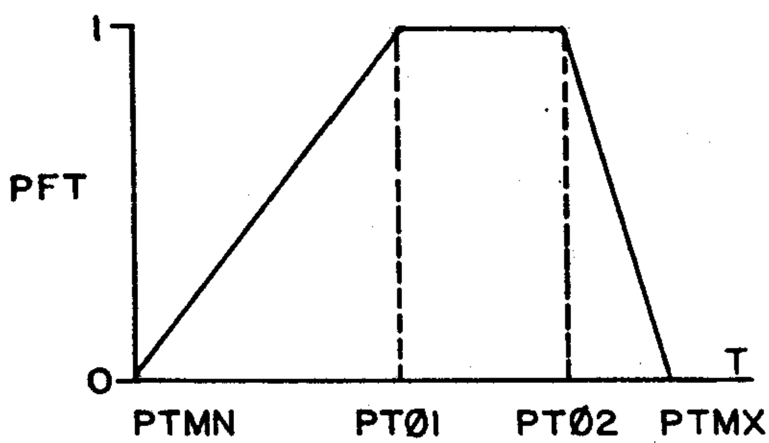


Fig. 3.

3. Response of NA to radiation (R) is a saturation function defined by two parameters (see Fig. 4).

PRC = radiation in cal/cm^2/day at the compensation point

PRS = radiation in cal/cm^2/day at saturation point

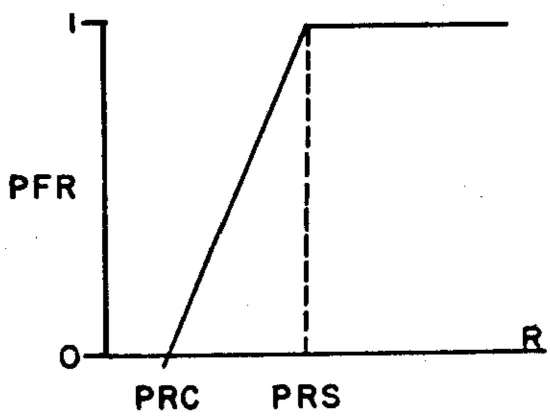


Fig. 4.

4. Response of NA to live green biomass (X_{21-24} in g/m^2 for the four plant types) is a constant relative growth rate until a maximum live green biomass (PXS) is reached. Then the relative growth rate decreases and the absolute growth rate becomes constant (see Fig. 5).

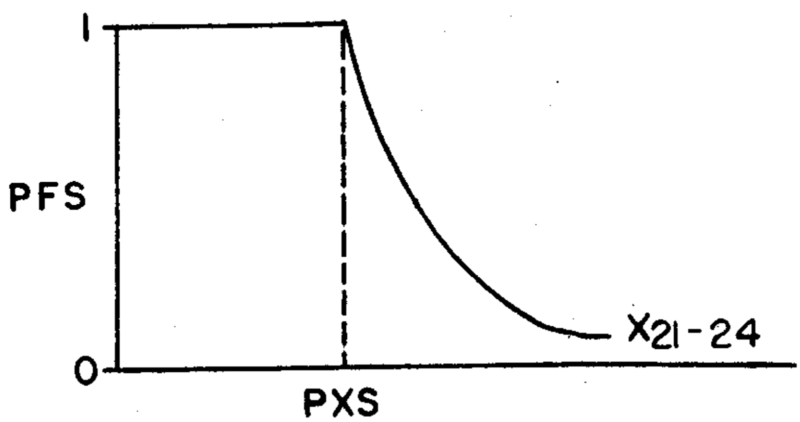


Fig. 5.

If X_{21-24} > PXS, PFS = PXS/X_{21-24}.

5. Response of NA to soil water (W) is a saturation curve defined by one parameter (PC), where PC = response at PWTR = 0.5 (see Fig. 6).

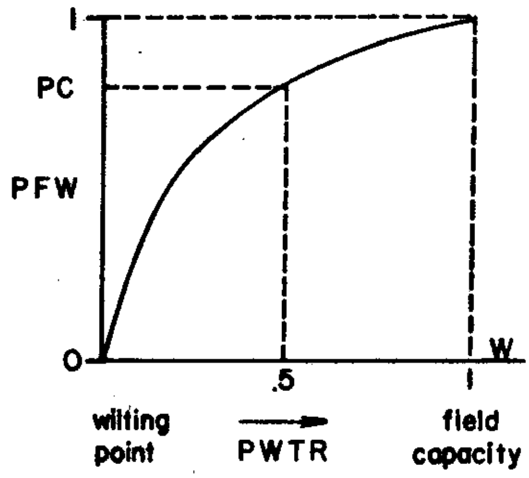


Fig. 6.

$$PFW = \frac{PC \cdot PWTR}{PC \cdot PWTR + (1 - PC)(1 - PWTR)}$$

where PWTR = water content weighted by root proportion [PROOT(I)] of each soil layer:

$$PWTR = \sum_{1}^{3} PROOT(I) \cdot PWW(I)$$

where PWW(I) is a standardized water content in each of the three soil layers.

$$PWW(I) = \frac{\theta - \theta_{15}}{\theta_{.3} - \theta_{15}}$$

where θ = volumetric water content in cm^3/cm^3 soil at the moment

$\theta_{.3}$ = volumetric water content at 0.3 atm in cm^3/cm^3 soil

θ_{15} = volumetric water content at 15 atm in cm^3/cm^3 soil

The effect of soil saturation was neglected.

Translocations

(i) *Live green-reserve* translocation (TSS) is the net flux between these compartments. The reserve compartment can be aboveground (wood, shoot bases, seeds) or belowground (rhizomes, bulbs, woody roots). The flow may be either positive (GREEN→RESERVE) or negative (RESERVE→GREEN). The amounts are given in g dry weight/m^2/day.

Assumptions:

1. At the beginning of the growing season there is a "reactivation flow" (germination in the case of annuals) (TSSA) from reserves (above and/or below) to green shoots. This flow starts when both soil water and air temperature are above a certain level (and not decreasing) and stops when the green biomass exceeds a certain level. This flow is expressed as:

$$TSSA = -PACTA/B \cdot X_{25-32} \cdot PHT \cdot PHW \cdot PHX21 \cdot (1 - PKD)$$

where PACTA/B = maximum rate of reserve activation (above = A/below = B)

X_{25-32} = any one of the reserve compartments

PHT = a factor due to temperature

PHW = a factor due to soil water

PHX21 = a factor due to existing green biomass

PKD = a factor due to deteriorating growth conditions

(PHT, PHW, PHX21 and PKD: between 0 and 1)

The effect of temperature on translocation between reserves and green shoots is described by a saturation function with the two parameters PTMNR and PTMXR (see Fig. 7).

PTMNR = threshold minimum temperature for reserve activation.

PTMXR = temperature at which the full reactivation rate is reached

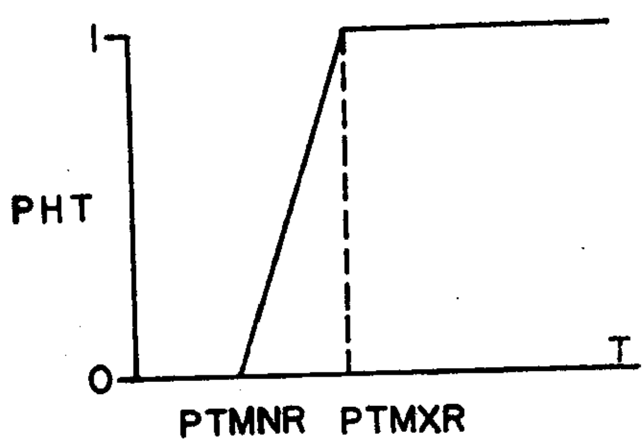


Fig. 7.

A similar response is assumed between standardized soil water and translocation (see Fig. 8).

PWMNR = minimum soil water for reserve reactivation

PWMXR = soil water at which full reactivation rate is reached

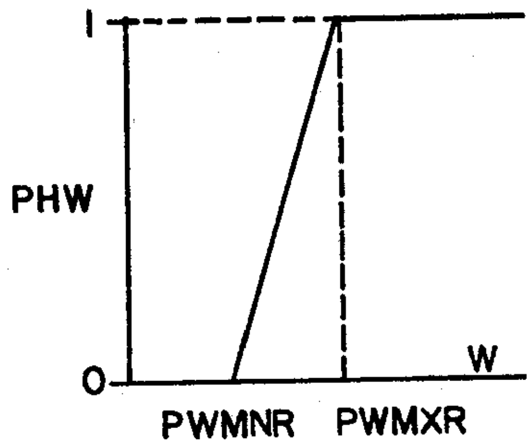


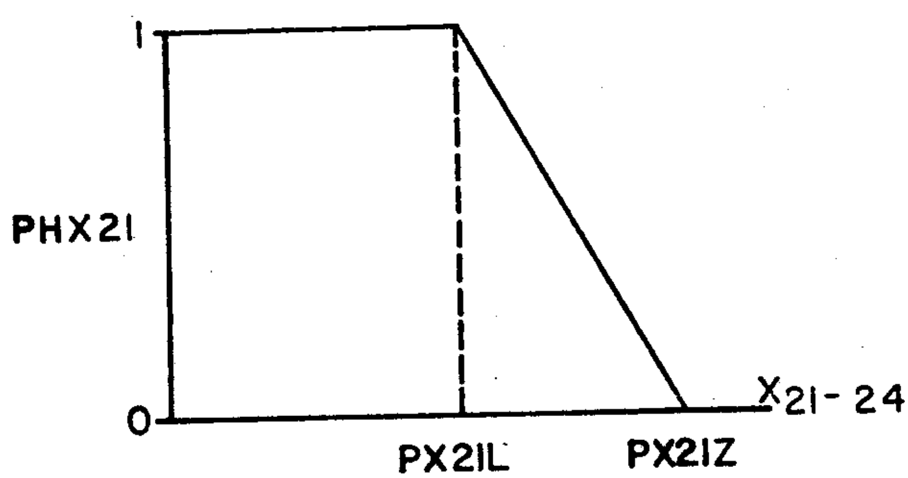
Fig. 8.

It is assumed that both reactivation from reserves to shoots in spring and downwards translocation is dependent on the amount of green biomass. The reactivation stops when the new green biomass reaches a certain level (see Fig. 9).

X_{21-24} = appropriate green biomass compartment in g/m^2

PX21L = green biomass level at which reserve reactivation begins to be depressed

PX21Z = green biomass level at which reserve reactivation stops



2. During the growing season there is a slow translocation flow (TSSB) from live green to reserves, taken to be a constant proportion of the green biomass (as long as this is above a certain threshold) (see Fig. 9 and 10).

$$TSSB = PTRMA/B \cdot X_{21-24} \cdot PTN \cdot PKX21$$

where PTRMA/B = relative translocation rate from live green to reserves (above = A/below = B) during the growing season

PTN = proportion of green biomass that is translocatable (excluding structural)

PKX21 = a factor due to minimum green biomass

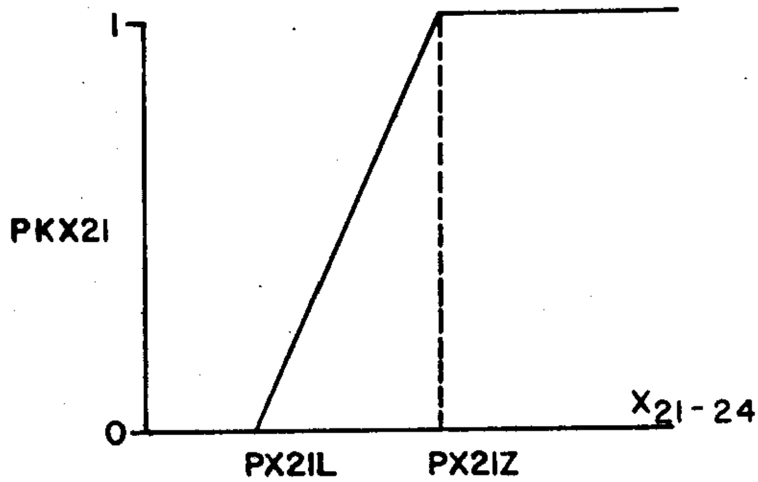


Fig. 10.

3. At the end of the growing season, as temperature and/or soil water and/or radiation decrease, and at shading by high green biomass, there is an accelerated "storage flow" (TSSC) from shoots to reserve which is proportional to the rate of deterioration in growing conditions.

$$TSSC = PSTMA/B \cdot PTN \cdot X_{21-24} \cdot PKD$$

where PSTMA/B = maximum relative rate of storage flow (above = A/below = B)

PTN = proportion of translocatable biomass in green shoots

PKD = a factor due to rate of environment deterioration (varying between 0 and 1)

PKD is dependent on temperature (PKDT), soil water (PKDW), shading (PKDS), and radiation (PKDR). When any of the factors are 1, PKD is set to 1. Otherwise PKD = (PKDT + PKDW + PKDS + PKDR)/NI where NI is number of non-zero contributing factors. PKD is only expected to work at the end of the growing season and is therefore set to zero under extremely unfavorable conditions, e.g., low temperatures (cutoff temperature).

For the factor PKDT due to low temperatures see Fig. 11.

PKDT1 = temperature below which PKDT = 1

PKDT2 = temperature where deterioration effect stops

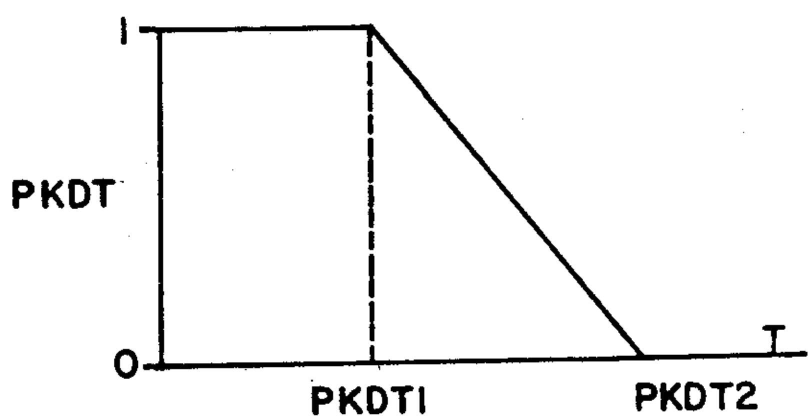


Fig. 11.

For the factor PKDW due to soil water (drought) see Fig. 12.

PKDW1 = standardized soil water below which PKDW = 1

PKDW2 = standardized soil water where deterioration effect stops

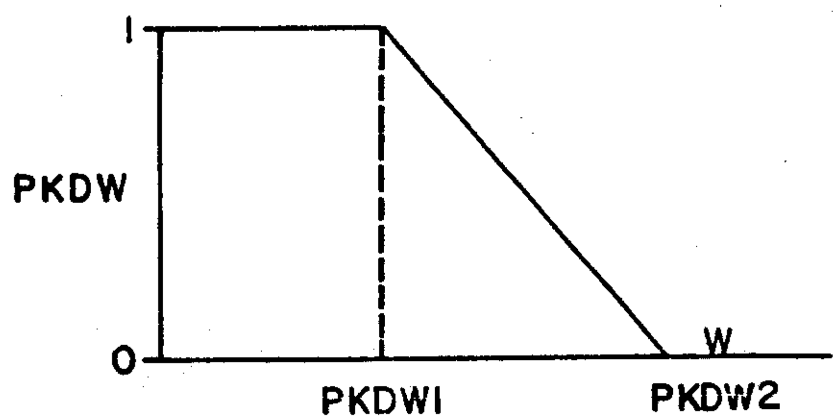


Fig. 12.

For the factor PKDS due to shading see Fig. 13.

PKDS1 = green biomass above which deterioration effect starts

PKDS2 = green biomass above which PKDS = 1

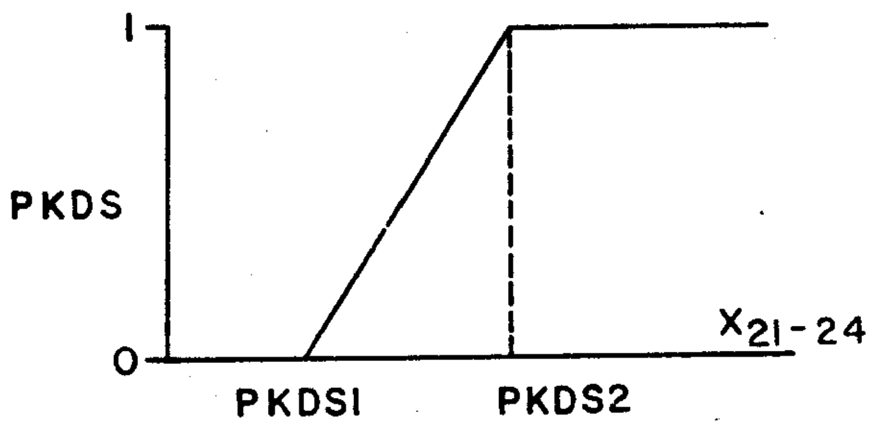


Fig. 13.

For the factor PKDR due to low radiation see Fig. 14.

PKDR1 = radiation below which PKDR = 1

PKDR2 = radiation where deterioration effect stops

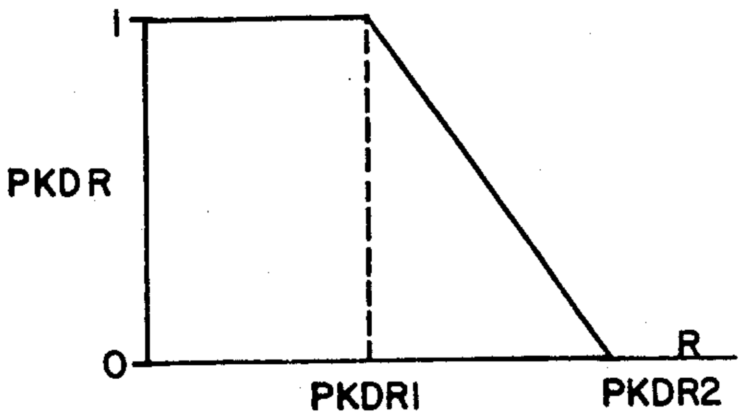


Fig. 14.

4. The total net shoot to reserve flow is taken to be the sum of the reactivation, constant translocation, and storage flows:

$$TSS = TSSA + TSSB + TSSC$$

TSSA is expected to be non-zero only at the beginning of the growing season, and TSSC only towards its end (or during a temporary decrease in growing conditions).

(ii) *Reserves-root* translocation (TRR) is defined as the flow of biomass from above- or belowground reserves to active roots.

Assumptions:

Reserve to root translocation occurs during the reactivation stage at the beginning of the growing season, and is proportional to the reactivation flow to the shoots at the same time. There is no back-flow from active roots at any time.

$$TRR = PACRA/B \cdot X_{25-32} \cdot PHT \cdot PHW \cdot PHX21$$

where PACRA/B = maximum rate of reserve (above = A/below = B) to root translocation. X_{25-32}, PHT, PHW, and PHX21 are defined in the reserve-shoot reactivation flow.

(iii) *Live green-Roots.* Shoot-root translocation (TSR) is the flow of biomass from green shoots to active roots.

Assumptions:

Shoot to root translocation occurs during the growing season (i.e., when green biomass is above a certain minimum and growth conditions are not deteriorating), and the rate is a constant proportion of green biomass.

$$TSR = PTRR \cdot X_{21-24} \cdot PKX21 \cdot (1 - PKD) \cdot PTN$$

where PTRR = maximum shoot-root translocation rate

PTN = proportion of translocatable material in green shoots

PKX21 = a factor due to minimum green biomass

PKD = a factor due to deteriorating growth conditions

Respiration

Above the compensation point, respiration is not modelled explicitly because it is included in the net assimilation flow.

Below the compensation point, a similar temperature-dependent respiration rate is assumed for both shoots and roots.

The response to temperature is assumed to be exponential, defined by two parameters, PRRO and PR20.

$$R_{21-24} = -(PRRO + (PR20 - PRRO)^{\frac{T}{20}}) \cdot X_{21-24}$$

where R_{21-24} = respiration flow of state variables X_{21-24} (green biomass)

PRRO = respiration rate at 0°C

PR20 = respiration rate at 20°C

T = temperature, air temperature for tops, soil temperature for roots. When $T < 0°C$, $R_{21-24} = 0$.

The respiration of reserves is considered to take place at a constant rate (-PRER), dependent only on biomass. $R_{25-32} = -PRER \cdot X_{25-32}$.

Death

Assumptions:

Death of green material is dependent upon air temperature (PMT), soil water (PMW), and the shading effect of the biomass itself (PMS). Death of the reserves above- and belowground (including the woody parts of shrubs) takes place at a constant rate (PDAR and PDBR, respectively). Death of roots is dependent on root biomass (X_{33-36}), the root/reserve ratio (PKRT), soil temperature (PMRT), and soil water (PMRW).

1. Death of green biomass, see Fig. 15 to 17.

Due to temperature, PMT:

PTD1 = lower temperature limit when green parts are dying at the maximum rate

PTD2 = lower temperature range at which death does not occur

PTD3 = upper limit of temperature at which death does not occur

PTD4 = upper limit of temperature at which death is maximum again

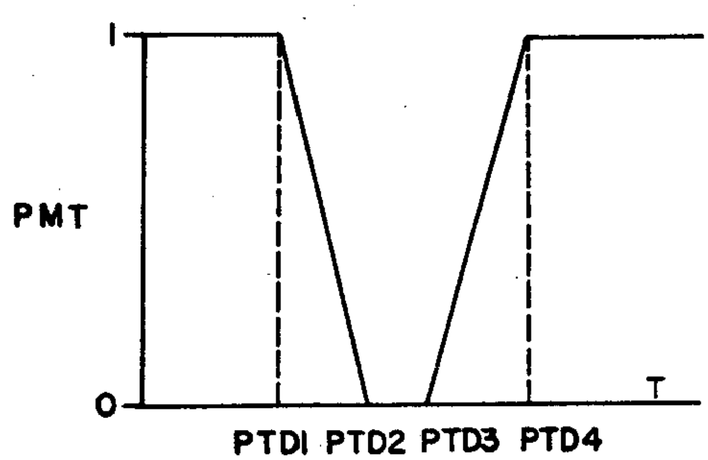


Fig. 15.

Due to soil water, PMW:

PWD1 = lower limit of soil water for maximum death

PWD2 = lower limit of soil water when no death occurs

PWD3 = soil water at which death occurs because of waterlogging

PWLD = death rate due to waterlogging

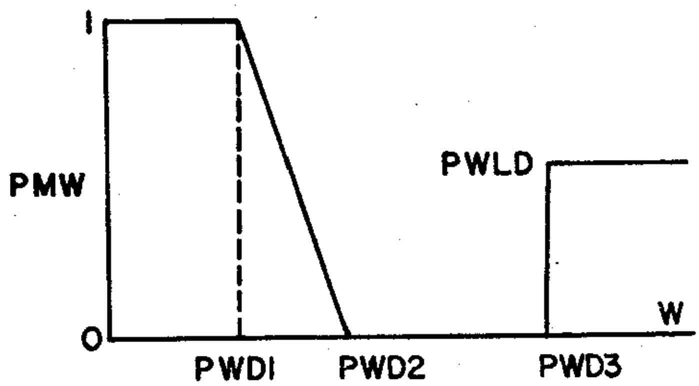


Fig. 16.

Due to shading, PMS:

PMGR = maximum death rate equals maximum growth rate

PXS = maximum standing crop (green)

PXM = amount of green biomass at which death begins due to self shading

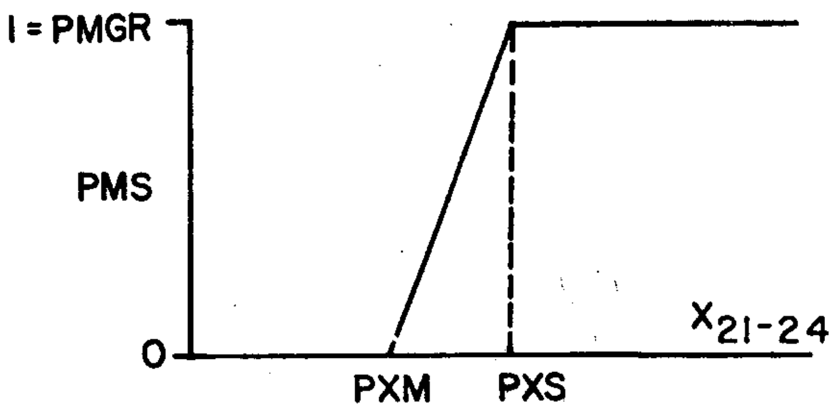


Fig. 17.

This means that maximal death rate due to shading is as high as maximal growth rate (PMGR). At the same time it is assumed that at highest possible amount of standing green biomass (PXS), death rate equals growth rate. Overall death function for death of green biomass is

$$PDTH = X_{21-24} \cdot (1 - (1 - PMT)(1 - PMW)(1 - PMS)) \cdot PDLG$$

where PDLG = maximum death rate of green biomass.

2. Death of reserves aboveground

$$PDTAR = X_{25-28} \cdot PDAR$$

Death of reserves belowground

$$PDTBR = X_{29-32} \cdot PDBR$$

where PDAR and PDBR are constants.

3. Death of roots, see Fig. 18.

Root death: $PDTR\emptyset = PCRDR \cdot X_{33-36} (1 + PKRT (1 - (1 - PMRT)(1 - PMRW)))$

where PCRDR = constant rate of root death

PMRW = PMW (i.e., the effect of soil water on root death is the same as for shoot death)

PMRT = effect of temperature on root death, and is calculated in the same way and with the same parameters as PMT, but using soil temperature (weighted by root density in the three soil layers) instead of air temperature

The PKRT factor allows for roots remaining alive during the non-growing season.

PRRR = root-reserve ratio during non-growing season

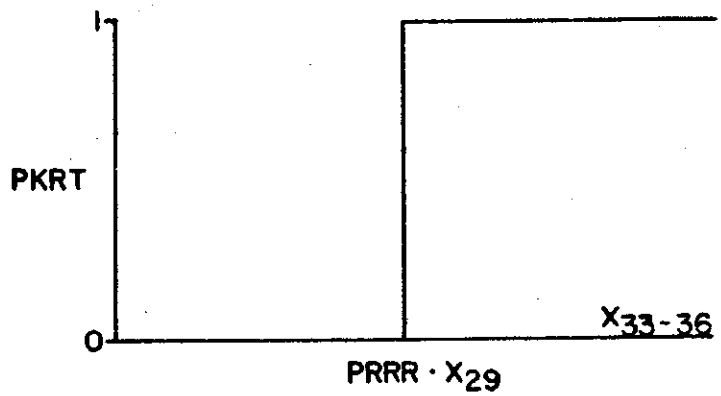


Fig. 18.

DECOMPOSITION SUBMODEL

The box-and-arrow diagram for the decomposition submodel is shown in Fig. 19. It is based on dead herbaceous and woody material of above- and belowground compartments, respectively, but dead cryptogams are treated separately. It is assumed that all aboveground material is transferred standing dead to litter, although leaves of shrubs often go directly from live green to litter. Litter, dead cryptogams, and belowground dead material are subdivided into three decomposition types, viz. "easy," "medium," and "difficult" according to ease of decomposition. "Easy" to decompose materials are, for example, soluble carbohydrates and proteins; materials "medium" to decompose are, for example, celluloses and hemicelluloses; while materials "difficult" to decompose are, for example, lignin, polyphenols, and silicon-rich materials. By making this distinction it is possible to get realistically different decomposition rates for various types of material which are dependent upon the proportions of the above components. In particular, this method will define a higher decomposition rate for recently dead material relatively richer in easy-decomposed soluble carbohydrates compared with older materials. When the dead plant material in the soil is no longer

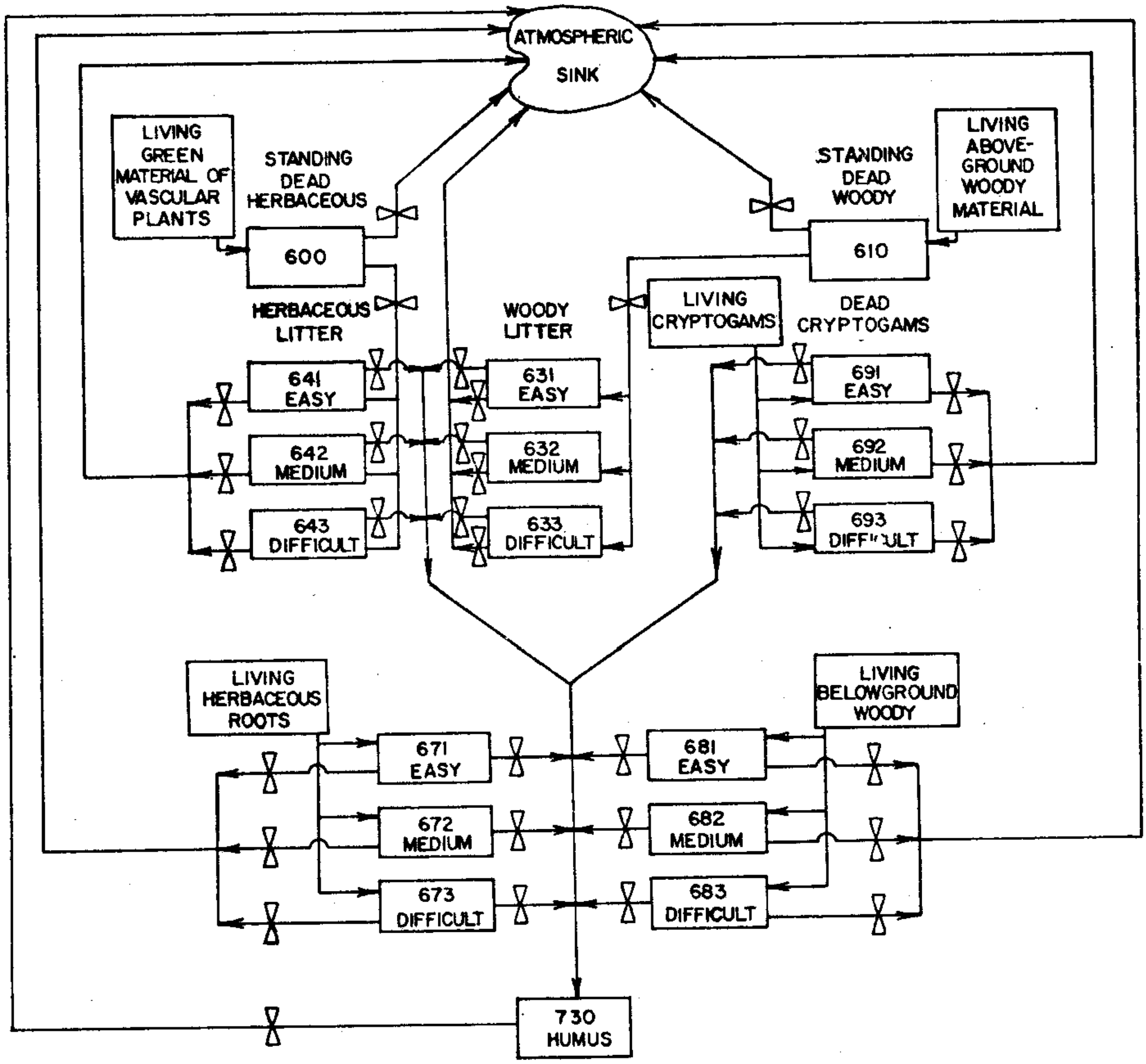


Fig. 19. Box-and-arrow diagram for the decomposer submodel.

recognizable as to origin, it is referred to as humus. All organic material is ultimately transferred to humus (X_{730}), which is decomposing due to the activity of microorganisms, as are all other state variables in the submodel.

Functional Description

Decomposition of standing dead

It is assumed that standing dead herbaceous (X_{600}) and woody (X_{610}) material of vascular plants decompose at site-specific fixed relative daily rates (g/g/day) which is higher for herbaceous ($D600_1$) than for woody ($D600_2$) material. In a higher resolution model this flow would be driven by air temperature, precipitation, and humidity. However, because death of material, according to the carbon submodel, varies with the climatic factors and thus time of the year, the highest decomposition is found in fall when the amount of standing dead is highest.

$$\text{Flow} = X_{600,610} \cdot D600_{1,2}$$

Transfer from standing dead to litter

This is also assumed to take place at a site-specific fixed relative daily rate (g/g/day) with different values for herbaceous ($D600_3$) and woody ($D600_4$) material. The material is separated into "easy," "medium," and "difficult" to decompose litter according to an assumed proportion of the different types of material in the herbaceous ($DP600_{1-3}$) and woody ($DP610_{1-3}$) litter. The flow from herbaceous standing dead to litter compartments is

$$\text{Flow} = X_{600} \cdot D600_3 \cdot DP600_{1-3}$$

The flow from shrubs standing dead to litter compartments is

$$\text{Flow} = X_{610} \cdot D600_4 \cdot DP610_{1-3}$$

Decomposition of litter

Decomposition of the two litter types takes place according to an assumed maximum daily relative rate (DMAXR) for the various proportions of "easy," "medium," and "difficult" to decompose material, modified by site-specific effects, varying between 0 and 1 for temperature (DET) and soil water (DEW) in the upper soil layer, pH of the litter (DEPH), and amount of nitrogen in the litter (DEN). The flows for decomposition of herbaceous and woody litter, respectively, are as follows

$$\text{Flow} = X_{641-643} \cdot DMAXR_{1-3} \cdot DET \cdot DEW \cdot DEPH \cdot DEN$$
$$\text{Flow} = X_{631-633} \cdot DMAXR_{4-6} \cdot DET \cdot DEW \cdot DEPH \cdot DEN$$

The flows are expressed as g/g/day for the three types of litter material from herbaceous and woody plants. $X_{641-643}$ and $X_{631-633}$ are the biomass of the three types in herbaceous and woody litter, respectively. $DMAXR_{1-3}$ are the daily maximum relative decomposition rates in g/g/day for the three types of herbaceous litter, and $DMAXR_{4-6}$ are similar values for woody litter.

1. The effect of temperature in the upper soil layer on decomposition of litter is a saturation function (DET) defined by two parameters (see Fig. 20).

DT64X(1) = minimum temperature in °C for decomposition

DT64X(2) = temperature above which decomposition is not limited

T = temperature in upper soil layer at a given moment

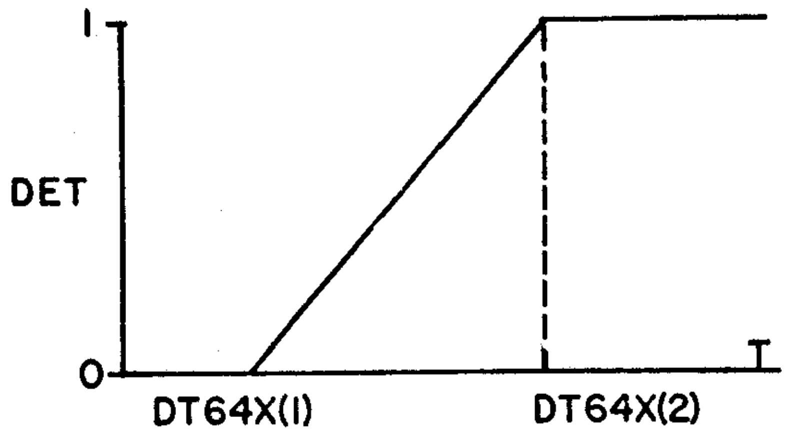


Fig. 20.

2. The effect of standardized soil water in the upper soil layer on decomposition of litter is a piecewise linear function (DEW) defined by four parameters (see Fig. 21).

DW64X(1) = minimum soil water amount (on a standardized scale) where decomposition takes place

DW64X(2) = lower limit of optimal soil water range for decomposition

DW64X(3) = upper limit of optimal soil water range for decomposition

DW64X(4) = maximum soil water for decomposition

W = soil water in upper soil layer at a given moment

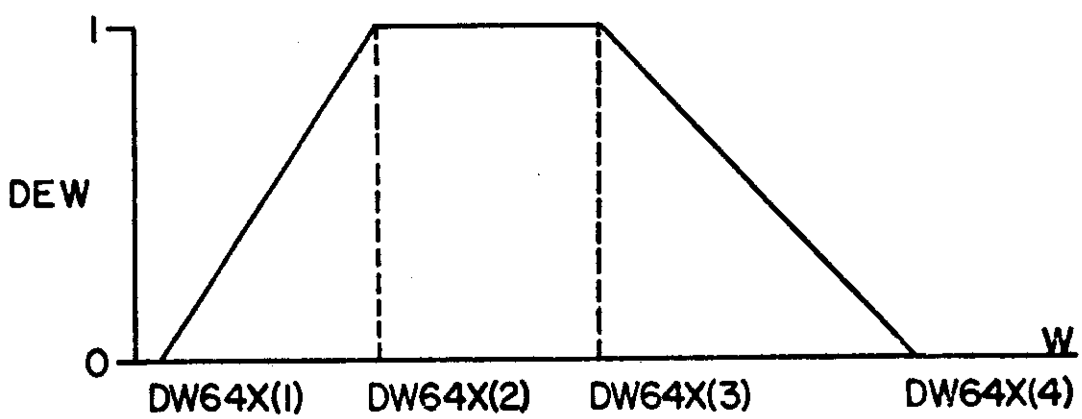


Fig. 21.

3. The effect of pH in the litter on decomposition is also a piecewise linear function (DEPH) defined by four parameters (see Fig. 22).

DH64X(1) = minimum pH for decomposition

DH64X(2) = lower limit of optimal pH range for decomposition

DH64X(3) = upper limit of optimal pH range for decomposition

DH64X(4) = maximum pH for decomposition

DPHCH = actual pH in herbaceous litter

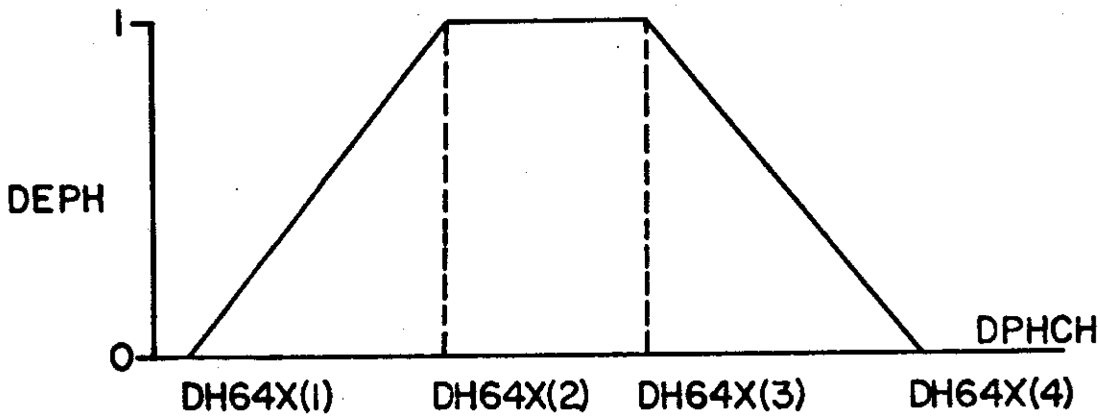


Fig. 22.

4. The effect of nitrogen percent in the litter on decomposition is a saturation function (DEN) defined by two parameters (see Fig. 23).

DN64X(1) = maximum nitrogen percent for decomposition

DN64X(2) = nitrogen percent from which decomposition is not limited by this parameter

CONCN = average nitrogen percent in herbaceous litter

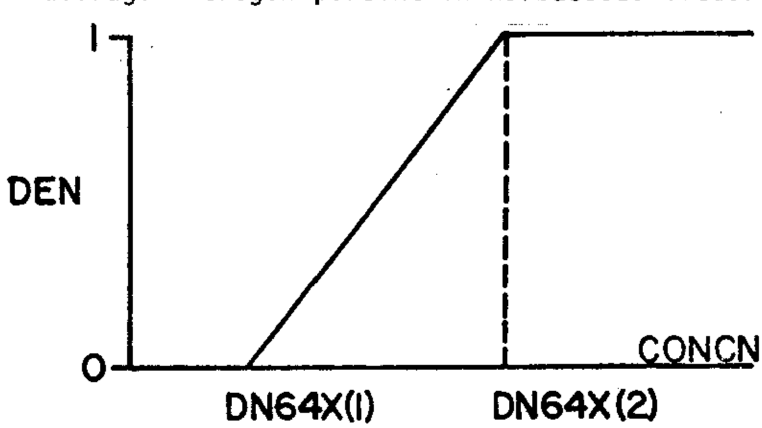


Fig. 23.

Decomposition of dead cryptogams

The same method as used for decomposition of litter is also used for decomposition of the three dead cryptogam categories. The temperature and water in the upper soil layer (chosen to be only 1 cm) are used to modify the maximum relative decomposition rate ($DMAXR_{7-9}$), and the pH (DPHCC) and nitrogen percent (CONCN) in the dead cryptogams are used to estimate the modifying effects of pH and nitrogen.

Decomposition of belowground dead

Decomposition of belowground dead herbaceous and woody material is assumed to be dependent on average soil temperature (PST) and average soil water for all three soil layers, as well as on pH and nitrogen percent of herbaceous belowground parts (DHCHR and CONCN) and woody belowground parts (DHCWR and CONCN). The functions for modifying the maximum daily relative decomposition rates ($DMAXR_{10-15}$) by these factors are as described for decomposition of litter.

Transfer of litter and belowground dead to humus

From all compartments an amount equal to that lost by decomposition to humus is transferred. This is a simplification, but little is known of actual transfer rates from various plant compartments to humus. As humus, by definition, is no longer recognizable as to species or plant group, the state variable "humus" has no subdivisions.

Decomposition of humus

The decomposition of humus was made dependent on the same variables as were used for belowground dead plants to modify the maximum relative decomposition rate per gram humus per day (DMXH).

NUTRIENT SUBMODEL

The nutrient submodel, which is closely linked to the producer and decomposer submodels, is depicted in the box-and-arrow diagram in Fig. 24. The objective was to design a framework which could have general applicability to all plant nutrients and yet at the same time allow for characteristic differences that exist between the flows of various elements through the ecosystem. In the present study the nutrient submodel has been applied to both phosphorus (P) and nitrogen (N), and in this case an example of the difference between the relationships for these two nutrients is highlighted by the importance and the flows associated with biological fixation of atmospheric N_2. While the model includes the possibility for fertilizer additions, these considerations are not included in the present study.

Nutrients are taken up from soil solutions by the roots and translocated to aboveground parts. For cryptogams it may be somewhat different, for although rhizoids of some mosses may be able to take up some nutrients, most of the nutrients in cryptogams will be taken up from water in lower parts of aboveground organs (partly depending on precipitation, but this is ignored here). In the model this is made possible by having the upper soil layer very thin and in close contact with the lower parts of what could be called the aboveground "reserves" of cryptogams (typical, for example, in mat-forming lichens) and by allowing the aboveground reserves to take up nutrients from this soil layer.

The nutrients are brought back to the soil via decomposition of the various main dead plant compartments used in the decomposer submodel. This neglects, as in the decomposer submodel, the importance of animal intake, especially of live aboveground material. In principle, however, this pathway

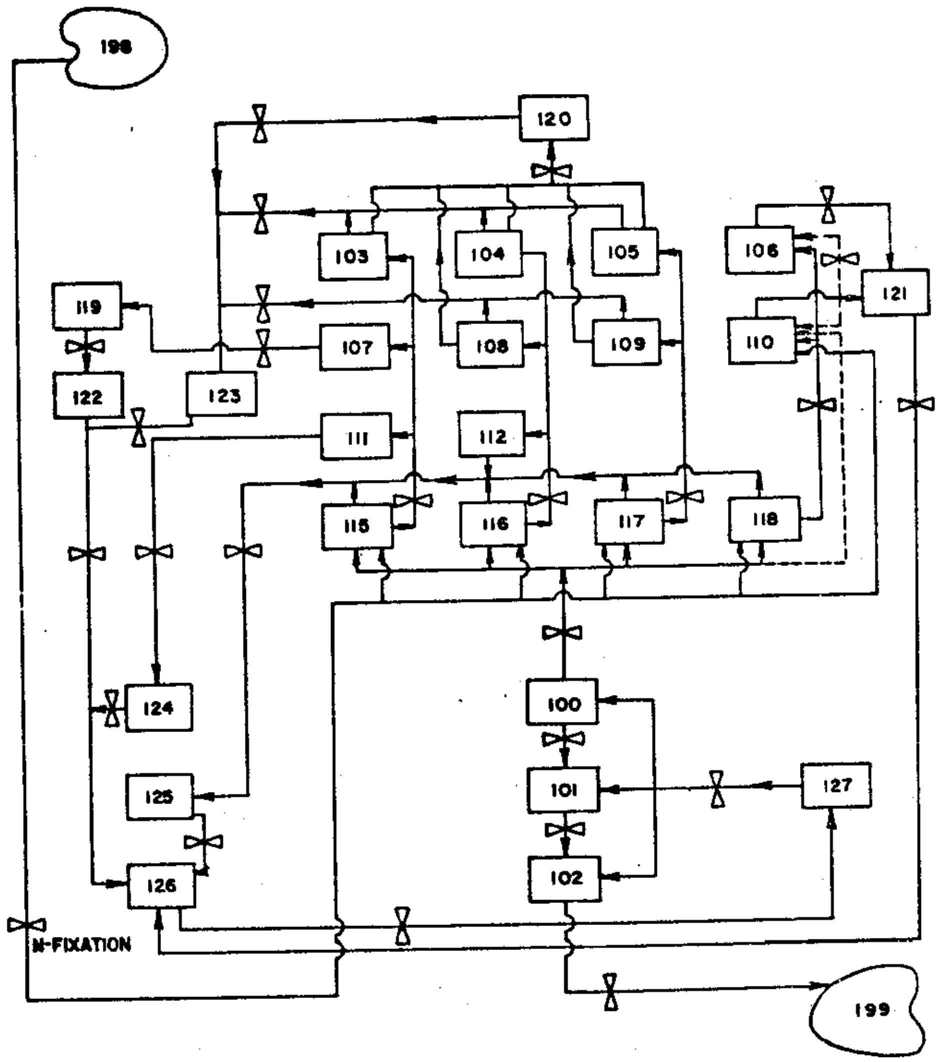


Fig. 24. Box-and-arrow diagram for nutrients (phosphorus is used as an example).

	Shrubs	Perennials	Annuals	Cryptogams
Green biomass	103	104	105	106
Aboveground reserves	107	108	109	110
Belowground reserves	111	112	--	--
Roots	115	116	117	(118)
Woody aboveground standing dead	119	--	--	--
Herbaceous aboveground standing dead	120	120	120	121
Woody litter	122	--	--	--
Herbaceous litter	123	123	123	121
Woody belowground dead	124	--	--	--
Herbaceous belowground dead	125	125	125	125
Humus (non-recognizable organic material)	126	126	126	126
Unavailable nutrients in soil		127		
Available nutrients in upper soil layer		100		
Available nutrients in middle soil layer		101		
Available nutrients in lower soil layer		102		
Nutrient source		198		
Nutrient sink (leaching)		199		

could be treated similarly to live-dead plant compartments giving transfer back to the system via urine and feces. Nutrients taken out of the system by grazing, harvesting, and leaching are then replaced by input from the source (X_{198}), including fertilizers.

The nitrogen fixed by root nodule organisms is taken to be easily available to the hosts and is fed directly into the roots (X_{33-36}). All nutrients may otherwise be released more or less slowly from an unavailable nutrient pool (X_{127}). The plants will take up part of the available nutrients from the three soil layers ($X_{100-102}$) during the growth period while some will be leached down the soil profile to the leachate sink (X_{199}), becoming unavailable to plant roots.

In the construction of the model the analogy between the flows of P and N is maintained in the numbering system for state variables and the nomenclature for flows and control parameters. The first number in the variable name indicates the mineral studied, e.g., X_{120} means P in standing herbaceous dead material, X_{220} means N in the same material, and so on. In the nitrogen submodel N replaces P in each variable name.

In the functional description which follows P has been used in all the examples given.

Functional Description

Release of nutrients from the unavailable pool (X_{127})

The maximum release of nutrients (FPMX) from the unavailable pool in the soil is dependent on the size of the pool (X_{127}) as well as on a site-specific character defining, for each of the nutrients, the maximum proportion that can flow into the available pool in each of three soil layers ($FP127_{1-3}$) in one day.

$$FPMX = X_{127} \cdot FP127_{1-3}$$

This maximum flow rate is modified by effects of average soil temperature (FPETP) and soil water (FPEWP) in the three layers as well as by the concentration in ppm of nutrients already in the available pool (FPECP).

$$Flow = FPMX \cdot FPETP \cdot FPEWP \cdot FPECP$$

1. The effect of soil temperature on flow rate from unavailable to available pools in each soil layer (FPETP) is a saturation function defined by two parameters (see Fig. 25).

FPST(1) = minimum temperature in °C for any flow

FPST(2) = temperature above which the flow is not limited by this parameter

PST = mean soil temperature at a given moment

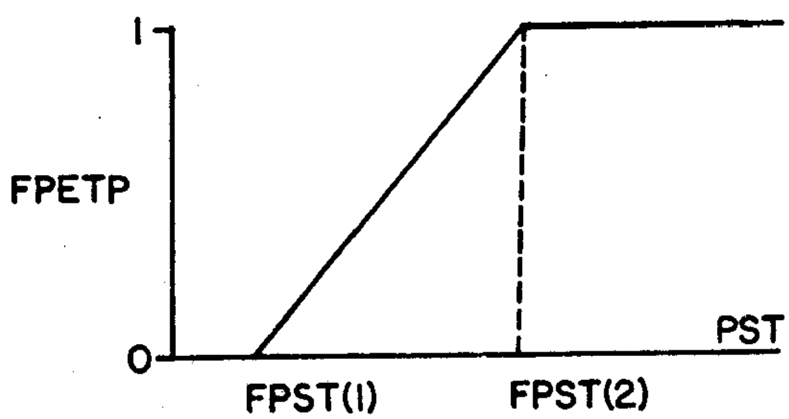


Fig. 25.

2. A similar function is used for the effect of mean soil water (FPEWP) on the flow rate with FPWT(1) = ASWP (wilting point) and FPWT(2) = ASFC (field capacity), respectively.

3. The opposite saturation function is assumed for the effect of concentration of available nutrients (FPECP) in the soil (see Fig. 26).

FPCP(1) = minimum concentration of nutrients below which flow is unaffected

FPCP(2) = concentration above which no flow occurs

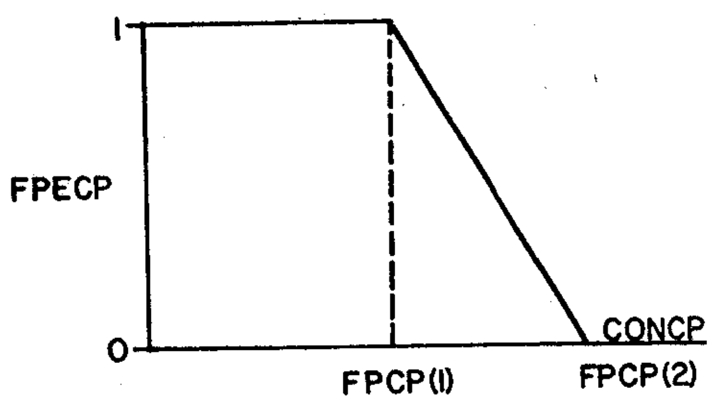


Fig. 26.

The actual nutrient concentration in ppm (CONCP) in each layer is calculated from the available nutrients and from the bulk densities. For example:

$$CONCP = X_{100-102}/(ASP_{1-3} \cdot ASODP \cdot ASBD_{1-3}) \cdot 1000$$

ASP_{1-3} = relative depths of soil layers

ASODP = total soil depth of interest in mm

$ASBD_{1-3}$ = bulk density in the three soil layers

Leaching of nutrient down the soil profile

The leaching of available nutrients from the three soil layers is dependent on the amount (g/m^2) of available nutrients in each of the layers $X_{100-102}$, the maximum proportion that will move out of a layer in one day under maximum water flow conditions (site-specific) (FPPRP), and a piecewise function of the amount of water in each of the layers. This function increases from 0 at field capacity (FPWL(1)) to a maximum of 1 at the volumetric water content (FPWL(2)) and decreases to 0 again for water-logged soil (FPWL(3)) (see Fig. 27).

$$\text{Flow} = \text{FPPRP} \cdot X_{100-102} \cdot f(\text{water})$$

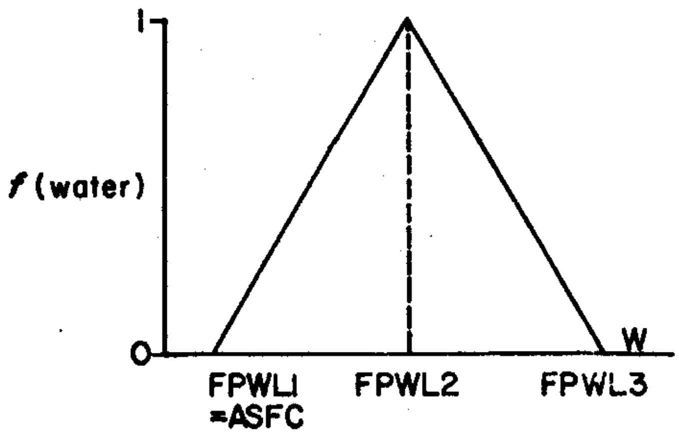


Fig. 27.

Uptake of nutrients from the soil

The uptake of nutrients by roots from the three soil layers is dependent on several factors. Each plant type has a maximum nutrient uptake (FPMXP) in g/g/root/day when all modifying factors are at an optimum. The root biomass (X_{33-36}) is important and so is the distribution of roots in the three soil layers (PROOT_{1-3}). The uptake is also proportional to the nutrient concentration (FPECP) in ppm in the three soil layers up to a limit and to growth rate of green biomass (FPEGP). The soil temperature in the three layers (FPETP) as well as the soil water (FPEWP) will also modify the uptake.

$$\text{Flow} = \text{FPMXP} \cdot X_{33-36} \cdot \text{PROOT}_{1-3} \cdot \text{FPECP} \cdot \text{FPEGP} \cdot \text{FPETP} \cdot \text{FPEWP}$$

1-3. The effect on uptake of the parameters FPECP, FPEGP, and FPETP are saturation functions defined by two parameters FPECX(1) and (2), and FPETX(1) and (2), respectively.

The actual concentration (CONCP), described earlier (see the section on "Release of nutrients from the unavailable pool"), is calculated from nutrients available and from bulk densities of these layers. The uptake of nutrients in relation to growth rate of green biomass (PMGR) is said to be 0 at PMGR = 0 and to increase to 1 at PMGR/2.

4. The effect of soil water on uptake from each layer is said to be a piecewise linear function defined by four parameters (see Fig. 28).

FPEWX(1) = minimum standardized soil water in the layers for nutrient uptake [set to ASWP + 0.4 (ASFC-ASWP) where ASWP = wilting point and ASFC = field capacity]

FPEWX(2) = lower limit of the optimal soil water range set to ASWP + 0.8 (ASFC-ASWP)

FPEWX(3) = upper limit of the optimal soil water range (equal to field capacity)

FPEWX(4) = maximum soil water for nutrient uptake

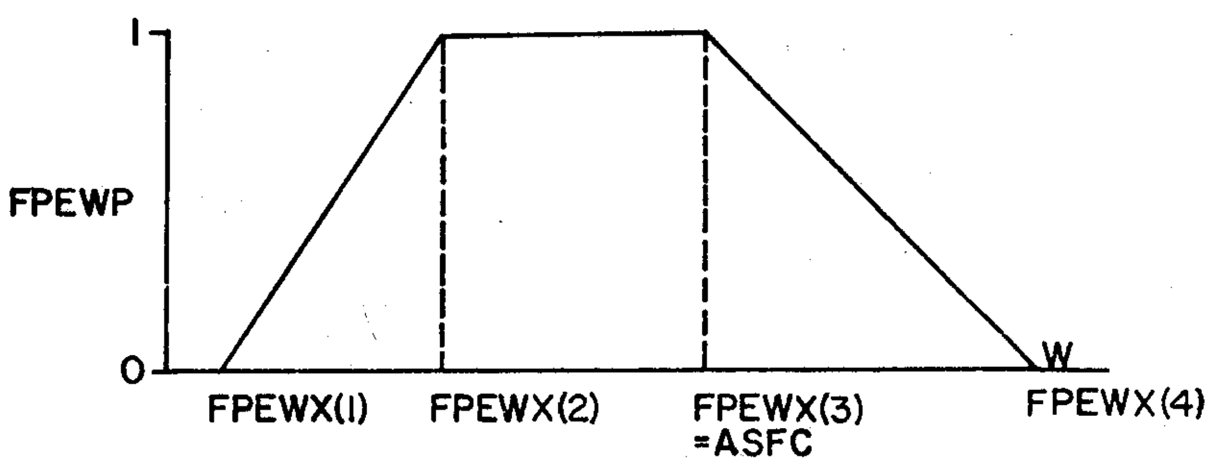


Fig. 28.

The uptake of nutrients by lichen aboveground reserves (X_{28}) is similar to that described above although only the conditions in the upper soil layer are taken into account and there is, of course, no root dependency.

$$Flow = FPMXP \cdot X_{28} \cdot FPECP \cdot FPEGP \cdot FPETP \cdot FPEWP$$

Fixation of nitrogen

The biomass of the nitrogen fixers is made a fixed proportion ($FNPNF_{1-4}$) of the total biomass, and their nitrogen/carbon ratios ($FNPER_{1-4}$) are made a constant for each plant type. The initial amount of N in the four compartments of each plant type is calculated allowing for their higher concentration of N. The N fixers are assumed to take up any available N that is in the soil layers in the same manner as the non-fixers. To maintain the correct N concentration in these plants, a proportion of the daily carbon flow is allocated to the N fixers using $FNPNF_{1-4}$, and sufficient N in addition to that taken up by their roots is fixed from the atmosphere (X_{298}) to make the N/C ratio of the daily flow equal to the predetermined constant ($FNPER_{1-4}$). Thus, the flow for additional N is

$$\begin{aligned} Flow &= FNPNF_{1-4} \cdot P121_{1-4} \cdot FNPER_{1-4} - FNPNF_{1-4} \cdot FN200_{1-4} \\ &= \text{amount of C flow} \cdot \text{N/C ratio} - \text{amount of N taken from the soil} \end{aligned}$$

where $FN200_{1-4}$ = total N flows from the soil for each of the four plant types

$P121_{1-4}$ = carbon flows to the four plant types

Cryptogams are treated in a similar manner.

Translocation of nutrients from the roots

The translocation of nutrients from roots to tops and to above- and belowground reserves is such that the nutrient/carbon ratio for each compartment within a plant type, relative to that for roots, is maintained at the initial values given. For example, $FPTRR_{I,J}$ is the P/C ratio for compartment I within plant type J relative to the P/C ratio in the roots of plant type J. It is expected that FPTRR for tops/root generally is above unity in the growing season. Similar relative ratios are given for other compartments of the various plant types, but will in practice often be close to unity.

The translocation within the plant will be dependent on the amount of nutrient taken up by the roots, the current nutrient status, and the current carbon assimilation. The nutrient flow within the plant is expressed by an equation of the form

$$\frac{X(K) + FK}{X(I)} = FPTRR \cdot \frac{X(L) + FP100-F1-F2-F3}{X(J)}$$

where X(I) and X(K) are the amounts of carbon and nutrient, respectively, in the compartment accepting the nutrient, and X(J) and X(L) are the amounts of carbon and nutrient, respectively, in the roots. F1, F2, and F3 are the flows of nutrient uptake to the tops, aboveground reserves, and belowground reserves, respectively, FK is either F1, F2, or F3 depending on the accepting compartment, and FP100 is the total amount of nutrient taken up by the roots from the three soil layers.

This generates a set of simultaneous equations in the unknown flows F1, F2, and F3 which are solved in the subroutine PFLOW. The term (FP100-F1-F2-F3) is, therefore, the amount of the nutrient uptake (FP100) which remains in the roots.

Transfer of nutrients to dead compartments

The transfer of nutrients from living to dead plant compartments and between dead compartments is made very simple in that the nutrient transfer is proportional to the transfer of carbon by decomposition between the compartments, but adjusted by specific proportionality factors for each plant type for relative nutrient/carbon transfers. These proportionality factors, however, are set to unity for all transfers between dead material. The general transfer will be

$$\text{Flow} = \text{DFlow} \cdot (\text{XF}/\text{XP}) \cdot \text{FPR}$$

where Flow = nutrient flow between various compartments, DFlow = death rates of living compartments (e.g., P2160 = death rate of green material to standing dead) according to the carbon submodel or transfer rates of dead material (e.g., D6064 = transfer in g/g/day of standing dead herbaceous to herbaceous litter) or decomposition rates of dead material (e.g., D6773 = respiration = decomposition of herbaceous root material in g/g/day transferring it to humus) according to the decomposer submodel. XF = nutrient amount in g/m^2 in donor compartment, XP = amount of carbon in donor compartment, and FPR = relative nutrient/carbon transfer ratio.

Transfer of nutrients from humus to unavailable soil pool

The transfer of nutrients from humus back to unavailable pool in the soil follows the same pattern as the transfer of dead plant material, i.e., proportional to the decomposition rate of humus and the nutrient/carbon ratio in humus.

The program for the producer, decomposer, and nutrient submodels is given in Table 1.

Table 1. Program for the model.

SIMCOMP Version 3.0 Source Listing 12/14/72

```
                C
                C      ABIOTIC STORAGE
                C
STORAGE.                ARMAX.ARMIN.ASFC(3).ASLAG(3).ASMAX(3).ASMIN(3).ASODP.ASP(3)
STORAGE.                ASWP(3).ATLAG.ATMAX.ATMIN.ATSMN(3).ATSMX(3).ATS1(3).ATS2(3)
STORAGE.                ATS3(3).ATS4(3).ASBD(3)
                C
                C      DECOMPOSER SECTION
                C
STORAGE.                DHCHR.DHCHU.DHCWR.DH64X(4).DH64Y(4).DMXH.DMAXR(15)
STORAGE.                DN64X(2).DN64Y(2).DNCC.DNCH.DNCHR.DNCHU.DNCW .DNCWR
STORAGE.                DPHCC.DPHCH.DPHCW.DP600(3).DP610(3).DP670(3).DP680(3).DP690(3)
STORAGE.                DRESP(15).DT64X(2).DT64Y(2).DW64X(4).DW64Y(4)
STORAGE.                D600(4).D610(4).D6064.D6163.D6373(2).D6773(2).D6973.D73
                C
                C      NITROGEN SECTION
                C
STORAGE.                FNCN(2).FNEC(2).FNECX(2).FNECY (2).FNEL(3).FNEGX (2).FNEGY(2)
STORAGE.                FNET(2).FNETX(2).FNETY(2).FNEW(2).FNEWX(4).FNEWY(4).FNMXN(4)
STORAGE.                FNN(16).FNPER(4).FNPNF(4).FNPRN.FNST(2).FNTRR(4.4).FNWL(3)
STORAGE.                FNWT(2).FN200(4).FN211 (6).FN220(6).FN221(2).FN227(4)
                C
                C      PHOSPHORUS SECTION
                C
STORAGE.                FPA (9).FPCP(2).FPEC(2).FPECX(2).FPECY(2).FPEL(3).FPFGX(2)
STORAGE.                FPEGY (2).FPET(2).FPETX(2).FPETY(2).FPEW(2).FPEWX(4).FPEWY(4)
STORAGE.                FPH(3).FPMXP(4).FPP(16).FPPRP.FPST(2).FPTRR(4.4).FPWL(3)
STORAGE.                FPWT(2).FX(4).FY(4).FZ(3).FP100(4).FP111(6).FP120(6).FP121(2)
STORAGE.                FP127(3).F1029.F1216.F1267.F2710(3)
                C
                C      CARBON SECTION
                C
STORAGE.                PACRA(4).PACRB(4).PACTA(4).PACTB(4)
STORAGE.                PC(4).PCNMN(2).PCONS.PCONW.PCRDR(4).PDAR(4).PDBR(4).PDF(4)
STORAGE.                PDLG(4).PFR(4).PFS(4).PFT(4).PFW(4)
STORAGE.                PHT(4).PHW(4).PHX21(4). PI. PJ. PK
STORAGE.                PKD(4).PKDMN. PKDR(4).PKDR1(4). PKDR2 (4)
STORAGE.                PKDS(4).PKDS1(4).PKDS2(4).PKDT(4).PKDT1(4).PKDT2(4)
STORAGE.                PKDW(4).PKDW1(4).PKDW2(4).PKM (4).PKRT(4).PKX21(4)
STORAGE.                PMGR(4).PMRT(4).PMRW(4).PMS(4).PMT(4).PMW(4)
STORAGE.                PNDF(4).PODF(4).PRC(4).PRER(4).PROOT(4.3).PRRO(4).PRRR(4)
STORAGE.                PRS(4)
STORAGE.                PR20(4).PST(4).PSTMA(4).PSTMB(4).PTD1(4).PTD2(4).PTD3(4)
STORAGE.                PTD4(4)
STORAGE.                PTMN(4).PTMNR(4).PTMX(4).PTMXR(4).PTN(4).PT01(4).PT02(4)
STORAGE.                PTRMA(4).PTRMB(4).PTRN(4).PTRR(4).PWD1(4).PWD2(4).PWD3(4)
STORAGE.                PWLD(4).PWMNR(4).PWMXR(4).PWTR.PWW(3).PXM(4).PXS(4)
STORAGE.                PXTRL(4).PX21L(4).PX21Z(4).P121(4).P2125(4).P2129(4).P2133(4)
STORAGE.                P2160(4).P2561(4).P2968 (4).P3367(4).P6373(3).P6473(4)
STORAGE.                P6773 (4).P6873(4).P6973(4).TABM.T24.T630.T640.T670.T680.T690
INTEGER.                PI.PJ.PK
STORAGE.                T106.WATER
STORAGE.                TDEN(3).TDEW(3).TDET(3).TDEPH(3)
                C
                C ... ESTIMATE THE RADIATION
(1-2).

                        FLOW=0.0
                        X(2)=(ARMIN+ARMAX)/2.+(ARMAX-ARMIN)/2.*SIN((TIME-90.)*3.14/180.)
                C ... ESTIMATE THE AIR TEMPERATURE
(1-3).

                        FAC = 3.14 / 180.0
                        ALAG = 90.0 + ATLAG
                        AMP = (ATMAX - ATMIN) * 0.5
                        AMEAN = (ATMAX + ATMIN) * 0.5
                        X(3) = AMEAN + AMP * SIN((TIME - ALAG) * FAC)
                        FLOW=0.0
                C ... SOIL TEMPERATURE IN TOP DEPTH LAGS AIR TEMP BY 5 DAYS
(1-4).

                        ALAG = 90.0 + ASLAG(1)
                        AMP = (ATSMX(1) - ATSMN(1)) * 0.5
                        AMEAN = (ATSMX(1) + ATSMN(1)) * 0.5
                        X(4) = AMEAN  +  AMP * SIN((TIME - ALAG) * FAC)
                        FLOW=0.0
```

```
              C ... SOIL TEMPERATURE IN 2ND DEPTH LAGS AIR TEMP BY 20 DAYS
(1-5).
                    ALAG = 90.0 + ASLAG(2)
                    AMP = (ATSMX(2) - ATSMN(2)) * 0.5
                    AMEAN = (ATSMX(2) + ATSMN(2)) * 0.5
                    X(5) = AMEAN  +  AMP * SIN((TIME - ALAG) * FAC)
                    FLOW=0.0
              C ... SOIL TEMPERATURE IN BOTTOM DEPTH LAGS AIR TEMP BY 30 DAYS
(1-6).
                    ALAG = 90.0 + ASLAG(3)
                    AMP = (ATSMX(3) - ATSMN(3)) * 0.5
                    AMEAN = (ATSMX(3) + ATSMN(3)) * 0.5
                    X(6) = AMEAN  +  AMP * SIN((TIME - ALAG) * FAC)
                    FLOW=0.0
              C ... ESTIMATE SOIL WATER CONTENT BY LAYERS
(1-J=10,12).
                    K=J-9
                    TT=TIME-ATS1(K)
                    AT2=ATS2(K)-ATS1(K)
                    AT3=ATS3(K)-ATS1(K)
                    AT4=ATS4(K)-ATS1(K)
                    IF(TT.LT.0.) TT=TT+360.0
                    TT=AMOD(TT,360.)
                    IF(AT2.LT.0.) AT2=AT2+360.
                    IF(AT3.LT.0.) AT3=AT3+360.
                    IF(AT4.LT.0.) AT4=AT4+360.
                    X(J)=ASMIN(K)
                    IF(TT.GT.AT4) GO TO 21001
                    IF(TT.GT.AT2) GO TO 21002
                    X(J)=X(J)+(ASMAX(K)-ASMIN(K))*TT/AT2
                    GO TO 21001
              21002 IF(TT.GT.AT3) GO TO 21003
                    X (J)=ASMAX(K)
                    GO TO 21001
              21003 X(J)=X (J)+(ASMAX(K)-ASMIN(K))*(AT4-TT)/(AT4-AT3)
              21001 FLOW=0.0
              C
              C ... FLOW FOR NET ASSIMILATION OF ABOVE GROUND LIVE GREEN
              C
(1-J=21,24).
                    PK=J-20
                    FLOW=PMGR(PK)*X(J)*PFT(PK)*PFW(PK)*PFR(PK)*PFS(PK)
                    IF(PFT(PK).LT.0.0.OR.PFW(PK).LT.0.0.OR.PFR(PK).LT.0.0)21004,21005
              21004 FLOW=AMIN1(0.,(-PRRO(PK)-(PR20(PK)-PRRO(PK))**(X(3)/20.))*X(J))
                   1 *PRRO(PK)
                    IF(X(3).LT.PTMNR(PK).OR. PWTR.LT.PWMNR(PK))    FLOW=0.0
              21005 P121(PK)=FLOW
              C
              C ... FLOW FOR RESPIRATION OF ABOVE-GROUND RESERVES
              C
(1-J=25,28).
                    PK=J-24
                    FLOW=-PRER(PK)*X(J)
              C
              C ... FLOW FOR RESPIRATION OF BELOW-GROUND RESERVES
              C
(1-J=29,32).
                    PK=J-28
                    FLOW=-PRER(PK)*X(J)
              C
              C ... FLOW FOR RESPIRATION OF ROOTS
              C
(1-J=33,36).
                    PK=J-32
                    FLOW=AMIN1(0.,(-PRRO(PK)-(PR20(PK)-PRRO(PK))**PST/20.)*X(J))*PRRO(
                   1PK)
                    IF(PST.LE.0.0) FLOW=0.0
              C
              C ... TRANSLOCATION GREEN TO ABOVE GROUND RESERVES
              C
(I=21,24-J=1*I+4).
                    PK=I-20
                    FLOW=-PACTA(PK)*X(J)*PHX21(PK)*PHW(PK)*PHT(PK)
                   1    +PTRMA(PK)*X(I)*PKX21(PK)*PTN(PK)
```

```
          2     +PSTMA(PK)*X(I)*PKD(PK)*PTN(PK)
           P2125(PK)=FLOW
    C
    C ... FLOW FROM GREEN TO BELOW-GROUND RESERVES.
    C
(I=21,24-J=1*I+8).

           PK=I-20
           FLOW=-PACTB(PK)*X(J)*PHX21(PK)*PHW(PK)*PHT(PK)
          1     +PTRMB(PK)*X(I)*PKX21(PK)*PTN(PK)
          2     +PSTMB(PK)*X(I)*PKD(PK)*PTN(PK)
           P2129(PK)=FLOW
    C
    C ... FLOW FOR TRANSLOCATION FROM GREEN TO ROOTS DIRECTLY
    C
(I=21,24-J=1*I+12).

           PK=I-20
           FLOW=PTRR(PK)*X(I)*(1.0-PKD(PK))*PTN(PK)*(1.-PHX21(PK))
           P2133(PK)=FLOW
    C
    C ... FLOW FOR TRANSLOCATION FROM ABOVE GROUND RESERVE TO ROOTS
    C
(I=25,28-J=1*I+8).

           PK=I-24
           FLOW=PACRA(PK)*X(I)*PHT(PK)*PHW(PK)*PHX21(PK)
    C
    C ... FLOW FOR CONSUMPTION OF ABOVE-GROUND BIOMASS
    C
(I=21,28-80).

           FLOW=0.0
           IF (X(3) .GT. PCNMN(1))  FLOW = X(I) * PCONS
           IF (X(3) .LT. PCNMN(2))  FLOW = X(I) *PCONW
    C
    C ... FLOW FOR TRANSLOCATION FROM BELOW GROUND RESERVE TO ROOTS
    C
(I=29,32-J=1*I+4).

           PK=I-28
           FLOW=PACRB(PK)*X(I)*PHT(PK)*PHW(PK)*PHX21(PK)
    C
    C ... FLOW FOR DEATH OF ABOVE GROUND GREEN MATERIAL (SHRUBS,PERENNIALS,ANNUALS)
    C
(I=21,23-60).

           PK=I-20
           FLOW=X(I)*(1.0-(1.0-PMT(PK))*(1.0-PMW(PK))*(1.0-PMS(PK)))*PDLG(PK)
           IF(FLOW*DT.GT.X(I)) FLOW=X(I)/DT
           P2160(PK)=FLOW
    C
    C ... FLOW FOR DEATH OF ABOVE GROUND GREEN MATERIAL (CRYPTOGAMS)

    C
(24-69).

           FLOW=X(24)*(1.0-(1.0-PMT(4))*(1.0-PMW(4))*(1.0-PMS(4)))*PDLG(4)
           IF(FLOW*DT.GT.X(24)) FLOW=X(24)/DT
           P2160(4)=FLOW
    C
    C ... FLOW FOR DEATH OF ABOVE GROUND RESERVES OF SHRUBS
    C
(25-61).

           FLOW=X(25)*PDAR(1)
           P2561(1)=FLOW
    C
    C ... FLOW FOR DEATH OF ABOVEGROUND RESERVES (PERENNIALS AND ANNUALS)
    C
(I=26,27-60).

           PK=I-24
           FLOW=X(I)*PDAR(PK)
           P2561(PK)=FLOW
    C
    C ... FLOW FOR DEATH OF ABOVE GROUND RESERVES OF CRYPTOGAMS
    C
(28-69).
```

```
                FLOW=X(28)*PDAR(4)
                P2561(4)=FLOW
          C
          C ... FLOW FOR DEATH OF BELOW-GROUND RESERVES OF SHRUBS
          C
(29-68).
                FLOW=X(29)*PDBR(1)
                P2968(1)=FLOW
          C
          C ... FLOW FOR DEATH OF BELOW GROUND RESERVES OF PERRENNIALS AND ANNUALS
          C
(I=30,31-67).
                PK=I-28
                FLOW=X(I)*PDBR(PK)
                P2968(PK)=FLOW
          C
          C ... FLOW FOR DEATH OF BELOWGROUND RESERVES OF CRYPTOGAMS
          C
(32-69).
                FLOW=X(32)*PDBR(4)
                P2968(4)=FLOW
          C
          C ... FLOW FOR DEATH OF ROOTS FOR SHRUBS, PERENNIALS, AND ANNUALS
          C
(I=33,35-67).
                PK=I-32
                FLOW=X(I)*PCRDR(PK)+X(I)*PKRT(PK)*(1.-(1.-PMRT(PK))*(1.-PMRW(PK)))
               1    *PCRDR(PK)
                IF(FLOW*DT.GT.X(I)) FLOW=X(I)/DT
                P3367(PK)=FLOW
          C
          C ... FLOW FOR DEATH OF ROOTS OF CRYPTOGAMS
          C
(36-69).
                FLOW=X(36)*PCRDR(4)+X(36)*PKRT(4)*(1.-(1.-PMRT(4))*(1.-PMRW(4)))
               1    *PCRDR(4)
                IF(FLOW*DT.GT.X(36)) FLOW=X(36)/DT
                P3367(4)=FLOW
          C
          C
          C     DECOMPOSER SECTION
          C
          C
          C ... D600(I=1,4) IS PROPORTION RESPIRED EACH DAY FROM X(600),X(610) TO X(1),AND
          C ... X(600) TO X(641,3) AND X(610) TO X(691,3)
          C ... DP600(I=1,3) PROPORTION FROM X(600) TO X(641),X(643) I.E. MATERIAL
          C ... WHICH IS EASY MEDIUM AND DIFFICULT TO DECOMPOSE
          C ... DP610(I=1,3) PROPORTION FROM X(610) TO X(631,3) I.E. MATERIAL WHICH
          C ... IS EASY, MEDIUM AND DIFFICULT TO DECOMPOSE
          C ... DMAXR(I=1,15) IS MAXIMUM RESPIRATION RATE IN G OF C/G OF C/DAY FOR
          C ... DECOMPOSER COMPARTMENTS 641,3 , 631,3 , 691,3 , 671,3 , 681,3 RESPECTIVELY
          C ... DP690(I=1,3) IS PROPORTION OF CRYPTOGAM LITTER WHICH IS EASY, MEDIUM
          C ... AND DIFFICULT TO DECOMPOSE ... X(691,3)
          C ... DP670(I=1,3) IS PROPORTION OF B.G.STANDING DEAD FOR PERENNIALS
          C ... AND ANNUALS WHICH IS EASY, MEDIUM AND DIFFICULT TO DECOMPOSE ... X(671,3)
          C ... DP680(I=1,3) IS PROPORTION OF B.G. DEAD WOODY MATERIAL WHICH IS EASY
          C ... MEDIUM AND DIFFICULT TO DECOMPOSE ... X(681,3)
          C ... DMXH IS MAXIMUM RATE OF BREAKDOWN OF HUMUS
          C     D6373(I=1,3) IS TOTAL FLOW FROM 631-633 AND 641-643 TO 730
          C     D6773(I=1,3) IS TOTAL FLOW FROM 681-683 AND 671-673 TO 730
          C     D6973 IS TOTAL FLOW FROM 691-693 TO 730
          C     D6064 IS TOTAL FLOW FROM 600 TO 641-643
          C     D6163 IS TOTAL FLOW FROM 610 TO 631-633
          C     ALIGN PRODUCER AND DECOMPOSER COMPARTMENTS
(60-600).
                FLOW=X(60)
          C     ALIGN PRODUCER AND DECOMPOSER COMPARTMENTS
(61-610).
                FLOW=X(61)
          C     ALIGN PRODUCER AND DECOMPOSER COMPARTMENTS
(69-I=691,693).
                FLOW=X(69)*DP690(I-690)
          C     ALIGN PRODUCER AND DECOMPOSER COMPARTMENTS
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```
(67-I=671,673).

                  FLOW=X(67)*DP670(I-670)
             C    ALIGN PRODUCER AND DECOMPOSER COMPARTMENTS
(68-I=681,683).

                  FLOW=X(68)*DP680(I-680)
(I=600,610,10-1).

             C ... THIS TRANSFER SHOULD BE DRIVEN BY AIR, TEMPERATURE, AND HUMIDITY
             C ... BUT IN THIS PROGRAM A CONSTANT PROPORTION IS TRANSFERRED
                  J=I/10-59
                  FLOW=X(I)*D600(J)
                  D6064=0.
(600-I=641,643).

                  FLOW=X(600)*D600(3)*DP600(I-640)
                  D6064=D6064+FLOW
                  D6163=0.
(610-I=631,633).

                  FLOW=X(610)*D600(4)*DP610(I-630)
                  D6163=D6163+FLOW
(I=641,643-1).

                  IF(X(I).LE.1.E-7) GO TO 10080
                  DMAX=X(I)*DMAXR(I-640)
             C ... CALCULATE THE AVERAGE CONCENTRATION OF N AS PER CENT
                  CONCN=X(223)/T640*100.
                  DEN=ALINT(DN64X,DN64Y,2,CONCN)
                  WATER=X(10)/(ASODP*ASP(1))
                  DEW=ALINT(DW64X,DW64Y,4,WATER)
                  DET=ALINT(DT64X,DT64Y,2,X(4))
             C ... PH CHANGES ARE NOT MODELLED BUT READ IN AS A PLANT SPECIFIC CHARACTER
                  DEPH=ALINT(DH64X,DH64Y,4,DPHCH)
                  FLOW=DMAX*DEN*DET*DEPH*DEW
                  GO TO 10081
             10080 FLOW=0.
             10081 DRESP(I-640)=FLOW
                  TDEN(I-640)=DEN
                  TDEW(I-640)=DEW
                  TDET(I-640)=DET
                  TDEPH(I-640)=DEPH
(I=631,633-1).

                  IF(X(I).LE.1.E-7) GO TO 10082
                  DMAX=X(I)*DMAXR(I-627)
             C ... CALCULATE THE AVERAGE CONCENTRATION OF N AS PER CENT
                  CONCN=X(222)/T630*100.
                  DEN=ALINT(DN64X,DN64Y,2,CONCN)
                  WATER=X(10)/(ASODP*ASP(1))
                  DEW=ALINT(DW64X,DW64Y,4,WATER)
                  DET=ALINT(DT64X,DT64Y,2,X(4))
                  DEPH=ALINT(DH64X,DH64Y,4,DPHCW)
                  FLOW=DMAX*DEN*DET*DEW*DEPH
                  GO TO 10083
             10082 FLOW=0.
             10083 DRESP(I-627)=FLOW
                  D6973=0.
(I=691,693-1).

                  IF(X(I).LE.1.E-7) GO TO 10084
                  DMAX=X(I)*DMAXR(I-684)
             C ... CALCULATE THE AVERAGE CONCENTRATION OF N AS PER CENT
                  CONCN=X(221)/T690*100.
                  DEN=ALINT(DN64X,DN64Y,2,CONCN)
                  WATER=X(10)/(ASODP*ASP(1))
                  DEW=ALINT(DW64X,DW64Y,4,WATER)
                  DET=ALINT(DT64X,DT64Y,2,X(4))
                  DEPH=ALINT(DH64X,DH64Y,4,DPHCC)
                  FLOW=DMAX*DEN*DET*DEW*DEPH
                  GO TO 10085
             10084 FLOW=0.
             10085 DRESP(I-684)=FLOW
                  D6973=D6973+FLOW
(I=671,673-1).

                  WATER=AVTEM=0.0
                  DO 1011 J=10,12
                  WATER=WATER+X(4)/ASODP
             1011 CONTINUE
                  IF(X(I).LE.1.E-7) GO TO 10086
                  DMAX=X(I)*DMAXR(I-661)
```

```
      C ... CALCULATE THE AVERAGE CONCENTRATION OF N AS PER CENT
            CONCN=X(225)/T670*100.
            DEN=ALINT(DN64X,DN64Y,2,CONCN)
            DEW=ALINT(DW64X,DW64Y,4,WATER)
            DET=ALINT(DT64X,DT64Y,2,PST)
            DEPH=ALINT(DH64X,DH64Y,4,DHCHR)
            FLOW=DMAX*DEN*DET*DEW*DEPH
            GO TO 10087
      10086 FLOW=0.
      10087 DRESP(I-661)=FLOW
(I=681,683-1).

            IF(X(I).LE.1.E-7) GO TO 10088
            DMAX=X(I)*DMAXR(I-668)
      C ... CALCULATE THE AVERAGE CONCENTRATION OF N AS PER CENT
            CONCN=X(224)/T680*100.
            DEN=ALINT(DN64X,DN64Y,2,CONCN)
            DEW=ALINT(DW64X,DW64Y,4,WATER)
            DET=ALINT(DT64X,DT64Y,2,PST)
            DEPH=ALINT(DH64X,DH64Y,4,DHCWR)
            FLOW=DMAX*DEN*DET*DEW*DEPH
            GO TO 10089
      10088 FLOW=0.
      10089 DRESP(I-668)=FLOW

            D6373(2)=0.
(I=641,643-730).

            FLOW=DRESP(I-640)
            D6373(2)=D6373(2)+FLOW
            D6373(1)=0.
(I=631,633,1-730).

            FLOW=DRESP(I-627)
            D6373(1)=D6373(1)+FLOW
(I=691,693-730).

            FLOW=DRESP(I-684)
            D6773(2)=0.
(I=671,673-730).

            FLOW=DRESP(I-661)
            D6773(2)=D6773(2)+FLOW
            D6773(1)=0.
(I=681,683-730).

            FLOW=DRESP(I-668)
            D6773(1)=D6773(1)+FLOW
(730-1).

      C ... DMXH IS MAXIMUM C/M*M/DAY THAT CAN GO OUT OF HUMUS
            DMAX=DMXH*X(730)
      C ... CALCULATE THE AVERAGE CONCENTRATION OF N AS PER CENT
            CONCN=X(226)/X(730)*100.
            DEN=ALINT(DN64X,DN64Y,2,CONCN)
            DEW=ALINT(DW64X,DW64Y,4,WATER)
            DET=ALINT(DT64X,DT64Y,2,PST)
            DEPH=ALINT(DH64X,DH64Y,4,DHCHU)
            FLOW=DMAX*DET*DEW*DEN*DEPH
            D73=FLOW
      C
      C     ****************************************************************
      C
      C     FNPER(I=1,4)  N/C RATIOS FOR N FIXERS
      C     FN227(I=1,3)  MAXIMUM PROP OF NON AVAIL N TRANSFERED TO AVAIL POOL /DAY
      C     CONCN  AVAILABLE SOIL N CONCENTRATION
      C     FN200(I=1,4)  FLOW OF N FROM SOIL TO EACH ROOT COMPARTMENT
      C     FNN(I=1,16)  INITIAL CONC OF N IN ALL PLANT COMPARTMENTS
      C     FNPNF(I=1,4)  PROPORTION OF N FIXERS IN EACH PLANT TYPE
      C     FNMXN(I=1,4)  MAXIMUM N UPTAKE RATE (GN/G ROOT/DAY)
      C     FNPRN  PROPORTION AVAILABLE N THAT WILL MOVE OUT OF A LAYER IN ONE
      C            DAY UNDER MAXIMUM WATER FLOW CONDITIONS
      C     FNWL(I=1,3)  X ARRAY FOR LEACHING LOSSES
      C     FNEL(I=1,3)  Y ARRAY FOR LEACHING LOSSES
      C     FNECX( I=1,2)  X ARRAY FOR N CONC EFFECT
      C     FNECY( I=1,2)  Y ARRAY FOR N CONC EFFECT
      C     FNETX(I=1,2)  X ARRAY FOR TEMPERATURE EFFECT
      C     FNETY(I=1,2)  Y ARRAY FOR TEMPERATURE EFFECT
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C      FNEWX(I=1,4)  X ARRAY FOR WATER CONTENT EFFECT
C      FNEWY(I=1,4)  Y ARRAY FOR WATER CONTENT EFFECT
C      FNFGX(I=1,2)  X ARRAY FOR GROWTH RATE EFFECT
C      FNEGY(I=1,2)  Y ARRAY FOR GROWTH RATE EFFECT
C      FNTRR(I=1,4,J=1,4)  RELATIVE N TO C RATIOS FOR EACH PRODUCER COMPARTMENT
C      FN221(I=1,2)  RELATIVE N TO C TRANSFER FOR CRYPTOGAMS LIVE GREEN
C                    AND A.G. RESERVES TO STANDING DEAD
C      FN211(I=1,6) RELATIVE N TO C TRANSFER OF B.G. RESERVES OF SHRUBS TO
C                    B.G. DEAD (WOODY)
C      FNST(I=1,2) X ARRAY FOR SOIL TEMPERATURE EFFECT
C      FNET(I=1,2)  Y ARRAY FOR SOIL TEMPERATURE EFFECT
C      FNWT(I=1,2) X ARRAY FOR SOIL WATER
C      FNEW(I=1,2)  Y ARRAY FOR SOIL WATER
C      FNCN(I=1,2)  X ARRAY FOR N CONC EFFECT
C      FNEC(I=1,2)  Y ARRAY FOR N CONC EFFECT
C      FN220(I=1,6)  RELATIVE N TO C TRANSFER FOR 4 PLANT TYPES INTO
C                    STANDING DEAD (203,204,205,207,208,-209)
C
C      ****************************************************************
C
(227-I=200,202).

C      TRANSFER OF N FROM NON-AVAIL SOIL POOL TO AVAIL N IN THREE SOIL LAYERS
       FNMX=X(227)*FN227(I-199)
       FNETN=ALINT(FNST,FNET,2,X(I-196))
C      ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
       FNWT(1)=ASWP(I-199)
       FNWT(2)=ASFC(I-199)
       WATER=X(I-190)/(ASP(I-199)*ASODP)
       FNEWN=ALINT(FNWT,FNEW,2,WATER)
       CONCN=X(I)/(ASP(I-199)*ASODP*ASBD(I-199))*1000.
C ...........CONCN IS MG/KG (PPM)
       FNECN=ALINT(FNCN,FNEC,2,CONCN)
       FLOW=FNMX*FNETN*FNEWN*FNECN
(200-201).

C      TRANSFER OF AVAILABLE N DOWN THE PROFILE INTO LEACHATE BUCKET
       FNMX=FNPRN*X(200)
C      ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
       FNWL(1)=ASFC(1)
       WATER=X(10)/(ASP(1)*ASODP)
       FLOW=FNMX*ALINT(FNWL,FNEL,3,WATER)
C
C      ****************************************************************
C
(201-202).

       FNMX=FNPRN*X(201)
C      ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
       FNWL(1)=ASFC(2)
       WATER=X(11)/(ASP(2)*ASODP)
       FLOW=FNMX*ALINT(FNWL,FNEL,3,WATER)
C
C      ****************************************************************
C
(202-299).

       FNMX=FNPRN*X(202)
C      ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
       FNWL(1)=ASFC(3)
       WATER=X(12)/(ASP(3)*ASODP)
       FLOW=FNMX*ALINT(FNWL,FNEL,3,WATER)
C
C      ****************************************************************
C
(I=200,202-J=215,218).

C      TRANSFER OF N FROM SOIL TO ROOT ..... NO COMPETITION IN THIS MODEL
       IF(X(J-182)    .LE.1.E-05) GO TO 41003
       IF(X(J-194)    .LE.1.E-05) GO TO 41003
       IF(P121(J-214).LE.1.E-09) GO TO 41003
       CONCN=X(I)/(ASP(I-199)*ASODP*ASBD(I-199))*1000.
       FNECN=ALINT(FNECX,FNECY,2,CONCN)
       FNETN=ALINT(FNETX,FNETY,2,X(I-196))
C      ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
       FNEWX(1)=ASWP(I-199)+0.4*(ASFC(I-199)-ASWP(I-199))
       FNEWX(2)=ASWP(I-199)+0.8*(ASFC(I-199)-ASWP(I-199))
       FNEWX(3)=ASFC(I-199)
       WATER=X(I-190)/(ASP(I-199)*ASODP)
       FNEWN=ALINT(FNEWX,FNEWY,4,WATER)
       FNEGX(2)=PMGR(I-199)/2.
       RGR=P121(J-214)/X(J-194)
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```
      IF((RGR-FNEGX(1)).LE.1.E-09) GO TO 41003
      FNEGN=ALINT(FNEGX,FNEGY,2,RGR)
      FLOW=FNMXN(J-214)*FNECN*FNETN*FNEWN*FNEGN*PROOT(I-199)*X(J-182)
      GO TO 41004
41003 FLOW=0.
41004 CONTINUE
      FN200(J-214)=FLOW+FN200(J-214)
C
C     ****************************************************************
C
(200-210).
C     FOR LICHENS TRANSFER OF N FROM SOIL TO A.G. RESERVES REPLACES SOIL TO ROOT
      FNEGX(2)=PMGR(4)/2.
      RGR=0.
      IF(X(24).GT.1.E-05)RGR=P121(4)/X(24)
      FNEGN=ALINT(FNEGX,FNEGY,2,RGR)
      ASS=ASP(1)*ASODP
      CONCN=X(200)/(ASS*ASRD(1))*1000.
      FNECN=ALINT(FNECX,FNECY,2,CONCN)
      FNETN=ALINT(FNETX,FNETY,2,X(4))
C     ADJUST FNEWX FOR CHARACTERISTICS OF SOIL LAYER
      FNEWX(1)=ASWP(1)+0.4*(ASFC(1)-ASWP(1))
      FNEWX(2)=ASWP(1)+0.8*(ASFC(1)-ASWP(1))
      FNEWX(3)=ASFC(1)
      WATER=X(10)/ASS
      FNEWN=ALINT(FNEWX,FNEWY,4,WATER)
      FLOW=FNMXN(4)*FNECN*FNETN*FNEWN*FNEGN*X(28)
      FN200(4)=FLOW
C
C     ****************************************************************
C
(298-J=215,218).
      FLOW=FNPNF(J-214)*(FNPER(J-214)*P121(J-214)-FN200(J-214))
C
C     ****************************************************************
C
(298-210).
C     LICHEN N FIXATION
      FLOW=0.
      IF(X(36).GT.1.E-08)
     1FLOW=FNPNF(4)*(FNPER(4)*P121(4)-FN200(4))
C
C     ****************************************************************
C
(215-J=203,211,4).
C     SET UP SIMULTANEOUS EQUATIONS TO ALLOCATE CURRENT FLOW OF N UPTAKE
C        BY ROOTS TO TOPS, A.G. RESERVES B.G. RESERVES --- WOODY
C     TRANSLOCATION IS MADE SO THAT THE N/C RATIOS FOR ANY PLANT CPT K
C     RELATIVE TO THAT FOR ROOTS IS PRESERVES AS FNTRR(K,1)
C
      IF(FN200(1).LE.1. E-9) GO TO 40008
      IF(J.EQ.203)40010,40012
40010 L=0
      DO 40001 K=1,4
      FX(K)=X(203+L)
      FY(K)=X(21+L)
40001 L=L+4
      DO 40002 K=1,3
40002 FZ(K)=FNTRR(K,1)
      CALL PFLOW(FX,FY,FZ,FN200(1),FPH,J)
40011 K=0
40012 K=K+1
      FLOW=FPH(K)
      GO TO 40009
40008 FLOW=0.
40009 CONTINUE
C
C     ****************************************************************
C
(216-J=204,212,4).
C     SIMULTANEOUS EQUATIONS FOR PERENNIALS
C     TRANSLOCATION IS MADE SO THAT THE N/C RATIOS FOR ANY PLANT CPT K
```

```
C     RELATIVE TO THAT FOR ROOTS IS PRESERVED AS FNTRR(K,2)
C
      IF(FN200(2).LE.1.E-09) GO TO 40015
      IF(J.EQ.204)40014,40016
40014 L=0
      DO 40017 K=1,4
      FX(K)=X(204+L)
      FY(K)=X(22+L)
40017 L=L+4
      DO 40117 K=1,3
40117 FZ(K)=FNTRR(K,2)
      CALL PFLOW(  FX,FY,FZ,FN200(2),FPH,J)
      K=0
40016 K=K+1
      FLOW=FPH(K)
      GO TO 40115
40015 FLOW=0.
40115 CONTINUE
C
C     ****************************************************************
C
(217-J=205,209,4).

C     SIMULTANEOUS EQUATIONS FOR ANNUALS
C     TRANSLOCATION IS MADE SO THAT THE N/C RATIOS FOR ANY PLANT CPT K
C     RELATIVE TO THAT FOR ROOTS IS PRESERVES AS FNTRR(K,3)
C
      IF (FN200(3).LE.1.E-9) GO TO 40120
      IF(J.EQ.205) 40018,40020
40018 L=0
      DO 40118 K=1,4
      FX(K)=X(205+L)
      FY(K)=X(23+L)
40118 L=L+4
      DO 40218 K=1,3
40218 FZ(K)=FNTRR(K,3)
      CALL PFLOW(  FX,FY,FZ,FN200(3),FPH,J)
      K=0
40020 K=K+1
      FLOW=FPH(K)
      GO TO 40220
40120 FLOW=0.
40220 CONTINUE
C
C     ****************************************************************
C
(218-J=206,210,4).

C     SIMULTANEOUS EQUATIONS FOR CRYPTOGAMS
C     TRANSLOCATION IS MADE SO THAT THE N/C RATIOS FOR ANY PLANT CPT K
C     RELATIVE TO THAT FOR ROOTS IS PRESERVES AS FNTRR(K,4)
C
      IF(FN200(4).LE.1.E-9) GO TO 40124
      IF(J.EQ.206)40022,40024
40022 L=0
      DO 40122 K=1,4
      FX(K)=X(206+L)
      FY(K)=X(24+L)
40122 L=L+4
      DO 40222 K=1,3
40222 FZ(K)=FNTRR(K,4)
      CALL PFLOW(   FX,FY,FZ,FN200(4),FPH,J)
      K=0
40024 K=K+1
      FLOW=FPH(K)
      GO TO 40224
40124 FLOW=0.
40224 CONTINUE
C
C     ****************************************************************
C
(210-206).

C     FLOW OF N IS ALLOCATED TO MAINTAIN SAME N/C RATIO IN TOPS RELATIVE TO THAT
C     IN A.G. RESERVES   FNTRR(1,4)/FNTRR(2,4)=N/C TOPS / N/C A.G. RESERVES
      DIV=0.0
      IF(FNTRR(1,4).LE.0.0.OR.FNTRR(2,4).LE.0.0) GO TO 40225
      T24FN=X(24)*FNTRR(1,4)/FNTRR(2,4)
      DIV=T24FN+X(28)
```

```
                40225 FLOW=0.0
                      IF(DIV.GT.1.E-05)FLOW=(T24FN*(X(210)+FN200(4))-X(206)*X(28))/DIV
                C
                C     ****************************************************************
                C
(I=203,205-220).
                C     TRANSFER OF N FROM GREEN MATERIAL TO A.G. STANDING DEAD (NON-WOODY)
                C
                      IF(X(I-182).LE.1.E-05) GO TO 41005
                      FLOW=P2160(I-202)/X(I-182)*X(I)*FN220(I-202)
                      GO TO 41006
                41005 FLOW=0.
                41006 CONTINUE
                C
                C     ****************************************************************
                C
(220-223).
                      FLOW=0.
                      IF(X(600).GT.1.E-05)FLOW=D6064*X(220)/X(600)
                C
                C     ****************************************************************
                C
(I=208,209-220).
                C     TRANSFER OF N FROM A.G. RESERVES OF PERENNIALS AND ANNUALS TO A.G.
                C        STANDING DEAD NON WOODY
                      IF(X(I-182).LE.1.E-05) GO TO 41007
                      FLOW=P2561(I-206)/X(I-182)*X(I)*FN220(I-203)
                      GO TO 41008
                41007 FLOW=0.
                41008 CONTINUE
                C
                C     ****************************************************************
                C
(206-221).
                C     TRANSFER OF N FROM GREEN CRYPTOGAMS TO A.G. STANDING DEAD CRYPTOGAMS
                C
                      IF(X(24).LE.1.E-05) GO TO 41009
                      FLOW=P2160(4)/X(24)*X(206)*FN221(1)
                      GO TO 41010
                41009 FLOW=0.
                41010 CONTINUE
                C
                C     ****************************************************************
                C
(221-226).
                      FLOW=0.
                      IF(T690.GT.1.E-05)FLOW=D6973*X(221)/T690
                C
                C     ****************************************************************
                C
(210-221).
                C     TRANSFER OF N IN A.G. RESERVES TO STANDING DEAD CRYPTOGAMS
                      IF(X(28).LE.1.E-05) GO TO 41011
                      FLOW=P2561(4)/X(28)*X(210)*FN221(2)
                      GO TO 41012
                41011 FLOW=0.
                41012 CONTINUE
                C
                C     ****************************************************************
                C
(207-219).
                C     TRANSFER OF N FROM A.G. WOODY RESERVES TO STANDING DEAD (WOODY)
                      IF(X(25).LE.1.E-05) GO TO 41013
                      FLOW=P2561(1)/X(25)*X(207)*FN220(4)
                      GO TO 41014
                41013 FLOW=0.
                41014 CONTINUE
                C
                C     ****************************************************************
                C
(219-222).
                      FLOW=0.
```

```
      IF(X(610).GT.1.E-05) FLOW=D6163 *X(219)/X(610)
C
C     ****************************************************************
C
(211-224).

C     TRANSFER OF N FROM B.G. SHRUBS TO B.G. DEAD (CF C FLOWS 29-68)
      IF (X(29).LE.1.E-05) GO TO 41015
      FLOW=P2968(1)/X(29)*FN211(1)*X(211)
      GO TO 41016
41015 FLOW=0.
41016 CONTINUE
C
C     ****************************************************************
C
(212-225).

C     TRANSFER OF N IN B.G. RESERVES OF PERENNIALS TO B.G. DEAD ROOTS
C        (CF CARBON FLOW 30-67)
      IF(X(30).LE.1.E-05) GO TO 41017
      FLOW=P2968(2)*X(212)/X(30)*FN211(2)
      GO TO 41018
41017 FLOW=0.
41018 CONTINUE
C
C     ****************************************************************
C
(I=215,218-225).

      IF(X(I-182).LE.1.E-05) GO TO 41019
      FLOW=P3367(I-214)*X(I)/X(I-182)*FN211(I-212)
      GO TO 41020
41019 FLOW=0.
41020 CONTINUE
      J=154
C
C     ****************************************************************
C
(I=224,225-226).

C     TRANSFERS OF N FROM BELOW G. DEAD WOODY TO HUMUS
C        (CF CARBON FLOWS 67,68-73)
      J=J+2
      K=(I-J)*10
      T681=X(K+1)+X(K+2)+X(K+3)
      FLOW=0.
      IF(T681.GT.1.E-5) FLOW=D6773(I-223)*X(I)/T681
C
C     ****************************************************************
C
(I=222,223-226).

C     TRANSFERS OF N FROM LITTER TO HUMUS  (CF CARBON FLOWS 62,63-73)


      FLOW=0.
      K=(I-159)*10
      T631=X(K+1)+X(K+2)+X(K+3)
      IF(T631.GT.1.E-5) FLOW=D6373(I-221)*X(I)/T631
C
C     ****************************************************************
C
(226-227).

C     TRANSFERS OF N OUT OF HUMUS TO NON-AVAIL N POOL
      IF(X(730).LE.1.E-05) GO TO 41025
      FLOW=D73*X(226)/X(730)
      GO TO 41026
41025 FLOW=0.
41026 CONTINUE
C
C     ****************************************************************
C
C     DEFINITIONS OF VARIABLE NAMES
C
C
C     FP 120(I=1,6)  RELATIVE P TO C TRANSFERS FOR 4 PLANT TYPES INTO
C     STANDING DEAD (103,104,105,107,108,109-120)
C
C     P2160(I=1,4)  CARBON FLOWS CALCULATED IN CARBON FLOW MODEL
C
C     P121     NET ASSIMILATION FLOW
```

```
      C
      C      ASP(I=1,3)  PROPORTION OF TOTAL SOIL DEPTH IN EACH OF THREE LAYERS
      C
      C      ASODP  ACTUAL SOIL DEPTH (CM)
      C
      C      ASWP(I=1,3)  WILTING POINT OF SOIL AT THREE DEPTHS
      C      ASFC(I=1,3) FIELD CAPACITY OF SOIL AT THREE DEPTHS
      C
      C      FPPRP PROPORTION OF AVAILABLE P THAT WILL MOVE OUT OF A LAYER IN ONE DAY
      C      UNDER MAXIMUM WATER FLOW CONDITIONS
      C
      C      FPWL(I=1,3) X ARRAY FOR LEACHING LOSSES
      C      FPEL(I=1,3) Y ARRAY FOR LEACHING LOSSES
      C
      C      PMGR(I=1,4) MAX RGR FOR EACH OF FOUR PLANT TYPES
      C
      C      FP121(I=1,2) RELATIVE P TO C TRANSFER FOR CRYPTOGAM LIVE GREEN
      C      AND A.G. RESERVES TO STANDING DEAD
      C
      C      P2561(I=1,4) CARBON FLOWS CALCULATED IN CARBON FLOW MODEL
      C
      C      FPTRR(I=1,4,J=1,4) RELATIVE P TO C RATIOS FOR EACH PRODUCER COMPARTMENT
      C         RELATIVE TO THAT FOR ROOTS
      C
      C      FP100 (I=1,4)  FLOWS OF P FROM SOIL TO ROOTS FOR FOUR PLANT TYPES
      C

      C      FP127(I=1,3)  SITE SPECIFIC CHARACTER DEFINING MAXIMUM PROPORTION OF
      C      NON-AVAILABLE P POOL THAT CAN FLOW TO AVAILABLE POOL IN ONE DAY
      C         INTO EACH OF THREE SOIL LAYERS
      C      FPST(I=1,2)  X ARRAY FOR SOIL TEMPERATURE EFFECT
      C      FPET(I=1,2)  Y ARRAY FOR SOIL TEMPERATURE EFFECT
      C
      C      FPWT(I=1,2)  X ARRAY FOR SOIL WATER EFFECT
      C      FPEW(I=1,2)  Y ARRAY FOR SOIL WATER EFFECT
      C
      C      ASBD(I=1,3)  SOIL BULK DENSITY FOR LAYERS 1-3 (G/CC)
      C
      C      FPCP(I=1,2)  X ARRAY FOR P CONC. EFFECT
      C      FPEC(I=1,2)  Y ARRAY FOR P CONC. EFFECT
      C
      C      FPMXP(I=1,4)  MAXIMUM P UPTAKE RATE (G/G ROOT/DAY) FOR EACH PLANT TYPE
      C
      C      FPECX(I=1,2) X ARRAY FOR P CONC. EFFECT
      C      FPECY(I=1,2) Y ARRAY FOR P CONC. EFFECT
      C
      C      FPFGX (I=1,2)  X ARRAY FOR GROWTH RATE EFFECT
      C      FPEGY (I=1,2)  Y ARRAY FOR GROWTH RATE EFFECT
      C
      C      FPETX(I=1,2)  X ARRAY FOR TEMPERATURE EFFECT
      C      FPETY(I=1,2)  Y ARRAY FOR TEMPERATURE EFFECT
      C      FPEWX (I=1,4) X ARRAY FOR WATER CONTENT EFFECT CALCULATED WITHIN PROGRAM
      C      FPEWY(I=1,4) Y ARRAY FOR WATER CONTENT EFFECT
      C
      C      FP111(I=1,6) RELATIVE P TO C TRANSFER OF B.G. RESERVES AND ROOTS TO
      C         B.G. DEAD (111,112,115,116,117,118,TO 125)
      C      B.G. DEAD (WOODY)
      C
      C      P2968 CARBON FLOWS FROM CARBON MODEL
      C
      C      P3367 CARBON FLOWS FROM CARBON MODEL
      C
      C ... PROOT(I=1,3) IS THE PROPORTION OF ROOT IN THE THREE SOIL LAYERS
      C
      C      ******************************************************************
      C
(127-I=100,102).

      C      TRANSFER OF P FROM NON-AVAIL SOIL POOL TO AVAIL P IN THREE SOIL LAYERS
             FPMX  =X(127)*FP 127(I-99)
             FPETP  =ALINT(FPST,FPET,2,X(I-96))
      C      ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
             FPWT(1)=ASWP(I-99)
             FPWT(2)=ASFC(I-99)
             WATER=X(I-90)/(ASP(I-99)*ASODP)
             FPEWP  =ALINT(FPWT,FPEW,2,WATER)
             CONCP=X(I)/(ASP(I-99)*ASODP*ASBD(I-99))*1000.
      C      CONCP IS IN MG/KG (PPM)
             FPECP  =ALINT(FPCP,FPEC,2,CONCP)
             FLOW=FPMX*FPETP*FPEWP*FPECP
```

```
      F2710(I-99)=FLOW
C
C
C     *************************************************************
C
C
C     TRANSFERS OF AVAIL P DOWN PROFILE AND INTO LEACHATE BUCKET
(100-101).

      FPMX=FPPRP*X(100)
C     ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
      FPWL(1)=ASFC(1)
      WATER=X(10)/(ASP(1)*ASODP)
      FLOW=FPMX*ALINT(FPWL,FPEL,3,WATER)
C
(101-102).

      FPMX=FPPRP*X(101)
C     ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
      FPWL(1)=ASFC(2)
      WATER=X(11)/(ASP(2)*ASODP)
      FLOW=FPMX*ALINT(FPWL,FPEL,3,WATER)
C
(102-199).

      FPMX=FPPRP*X(102)
C     ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
      FPWL(1)=ASFC(3)
      WATER=X(12)/(ASP(3)*ASODP)
      FLOW=FPMX*ALINT(FPWL,FPEL,3,WATER)
      F1029=FLOW
C
C
C     *************************************************************
C
C
(I=100,102-J=115,118).

C     TRANSFERS OF P FROM SOIL TO ROOT
C     IN THIS VERSION THERE IS NO COMPETITION FOR AVAILABLE P BETWEEN TYPES
C     E.G. PLANT TYPES COULD BE GIVEN DIFFERENT PRIORITIES TO TAKE UP NUTRIENTS
      IF(X(J-82)          .LE.1.E-05) GO TO 31003
      IF(X(J-94)          .LE.1.E-05) GO TO 31003
      IF(P121(J-114)      .LE.1.E-09) GO TO 31003
      CONCP=X(I)/(ASP(I-99)*ASODP*ASHD(I-99))*1000.
      IF((CONCP-FPECX(1))   .LE.1.E-05) GO TO 31003
      FPECP =ALINT(FPEC  X,FPEC  Y,2,CONCP)
      IF((X(I-96)-FPETX(1)).LE.1.E-05) GO TO 31003
      FPETP=ALINT(FPET  X,FPET  Y,2,X(I-96))
C     ADJUST EFFECT OF WATER CONTENT ARRAY FOR CHARACTERISTICS OF LAYER
      FPEW X(1)=ASWP(I-99)+0.4*(ASFC(I-99)-ASWP(I-99))
      FPEW X(2)=ASWP(I-99)+0.8*(ASFC(I-99)-ASWP(I-99))
      FPEW X(3)=ASFC(I-99)
      WATER=X(I-90)/(ASP(I-99)*ASODP)
      IF((WATER-FPEWX(1))   .LE.1.E-05) GO TO 31003
      FPEWP =ALINT(FPEW X,FPEW Y,4,WATER)
      FPEG X(2)= PMGR (I-99)/2.
      RGR=P121(J-114)/X(J-94)
      IF((RGR-FPEGX(1))    .LE.1.E-05) GO TO 31003
      FPEGP =ALINT(FPEG X,FPEG Y,2,RGR)
      FLOW=FPMX P(J-114)*FPECP *FPETP *FPEWP *FPEGP *PROOT(I-99)*X(J-82)
      GO TO 31004
31003 FLOW=0.
31004 CONTINUE
      FP100 (J-114)=FLOW+FP100(J-114)
(100-110).

C     FOR LICHENS TRANSFER OF P FROM SOIL TO A.G. RESERVES REPLACES SOIL TO ROOT
      FPEGX(2)=PMGR (4)/2.
      RGR=0.
      IF(X(24).GT.1.E-05) RGR=P121(4)/X(24)
      FPEGP=ALINT(FPEGX,FPEGY,2,RGR)
      ASS=ASP(1)*ASODP
      CONCP=X(100)/(ASS*ASHD(1))*1000.
      FPECP=ALINT(FPECX,FPECY,2,CONCP)
      FPETP=ALINT(FPETX,FPETY,2,X(4))
C     ADJUST FPEWX FOR CHARACTERISTICS OF LAYER
      FPEWX(1)=ASWP(1)+.4*(ASFC(1)-ASWP(1))
      FPEWX(2)=ASWP(1)+.8*(ASFC(1)-ASWP(1))
      FPEWX(3)=ASFC(1)
      WATER=X(10)/ASS
      FPEWP=ALINT(FPEWX,FPEWY,4,WATER)
      FLOW=FPMXP(4)*FPECP*FPETP*FPEWP*FPEGP*X(28)
      FP100(4)=FLOW
```

```
      C
      C     ***************************************************************
      C
(115-J=103,111,4).

      C
      C ... SET UP SIMULTANEOUS EQUATIONS TO ALLOCATE CURRENT FLOW OF P
      C ... TRANSLOCATION FROM ROOTS TO TOPS, A.G. RESERVES, B.G. RESERVES ---- WOODY
      C ... TRANSLOCATION IS MADE SO THAT THE P/C RATIO FOR ANY PLANT COMPARTMENT K
      C ... RELATIVE TO THAT FOR ROOTS IS PRESERVED AS FPTRR(K,1)
      C     ******   NETT  FLOWS     **********
      C
            IF(FP100(1).LE.1.E-9) GO TO 30008
            IF(J.EQ.103) 30010,30012
      30010 L=0
            DO 30001 K=1,4
            FX(K)=X(103+L)
            FY(K)=X(21+L)
      30001 L=L+4
            DO 30002 K=1,3
      30002 FZ(K)=FPTRR(K,1)
            CALL PFLOW(FX,FY,FZ,FP100(1),FPH,J)

      30011 K=0
      30012 K=K+1
            FLOW=FPH(K)
            GO TO 30009
      30008 FLOW=0.
      30009 CONTINUE
(116-J=104,112,4).

      C
      C ... SIMULTANEOUS EQUATIONS FOR PERENNIALS
      C ... TRANSLOCATION IS MADE SO THAT THE P/C RATIO FOR ANY PLANT COMPARTMENT K
      C ... RELATIVE TO THAT FOR ROOTS IS PRESERVED AS FPTRR(K,2)
      C     ******    NETT  FLOWS     **********
      C
            IF(FP100(2).LE.1.E-9) GO TO 30015
            IF(J.EQ.104) 30014,30016
      30014 L=0
            DO 30017 K=1,4
            FX(K)=X(104+L)
            FY(K)=X(22+L)
      30017 L=L+4
            DO 30117 K=1,3
      30117 FZ(K)=FPTRR(K,2)
            CALL PFLOW(FX,FY,FZ,FP100(2),FPH,J)
            K=0
      30016 K=K+1
            FLOW=FPH(K)
            GO TO 30115
      30015 FLOW=0.
      30115 CONTINUE
(117-J=105,109,4).

      C
      C ... SIMULTANEOUS EQUATIONS FOR ANNUALS
      C ... TRANSLOCATION IS MADE SO THAT THE P/C RATIO FOR ANY PLANT COMPARTMENT K
      C ... RELATIVE TO THAT FOR ROOTS IS PRESERVED AS FPTRR(K,3)
      C
      C     ******     NETT  FLOWS     **********
            IF(FP100(3).LE.1.E-9) GO TO 30120
            IF(J.EQ.105) 30018,30020
      30018 L=0
            DO 30118 K=1,4
            FX(K)=X(105+L)
            FY(K)=X(23+L)
      30118 L=L+4
            DO 30218 K=1,3
      30218 FZ(K)=FPTRR(K,3)
            CALL PFLOW(FX,FY,FZ,FP100(3),FPH,J)
            K=0
      30020 K=K+1
            FLOW=FPH(K)
            GO TO 30220
      30120 FLOW=0.
```

```
              30220 CONTINUE
(118-J=106,110,4).
              C ... SIMULTANEOUS EQUATIONS FOR CRYPTOGAMS
              C ... TRANSLOCATION IS MADE SO THAT THE P/C RATIO FOR ANY PLANT COMPARTMENT K
              C ... RELATIVE TO THAT FOR ROOTS IS PRESERVED AS FPTRR(K,4)
                    IF(X(36).LE.1.E-4) GO TO 30124
                    IF(J.EQ.106) 30022,30024
              30022 L=0
                    DO 30122 K=1,4
                    FX(K)=X(106+L)
                    FY(K)=X(24+L)
              30122 L=L+4
                    DO 30222 K=1,3
              30222 FZ(K)=FPTRR(K,4)
                    CALL PFLOW(FX,FY,FZ,FP100(4),FPH,J)
                    K=0
              30024 K=K+1
                    FLOW=FPH(K)
                    GO TO 30224
              30124 FLOW=0.
              30224 CONTINUE
(110-106).
              C     FLOW OF P FROM 110-106 ALLOCATED ACCORDING TO PROPN. OF DRY MATTER
              C     FLOW OF P FROM 110-106 IS ALLOCATED TO MAINTAIN THE SAME P/C RATIO
              C     IN TOPS RELATIVE TO A.G. RESERVES
              C        FPTRR(1,4)/FPTRR(2,4)=P/C TOPS /P/C A.G. RESERVES
                    DIV=0.0
                    IF(FPTRR(1,4).LE.0.0.OR.FPTRR(2,4).LE.0.0) GO TO 30225
                    T24FP=X(24)*FPTRR(1,4)/FPTRR(2,4)
                    DIV=T24FP+X(28)
              30225 FLOW=0.0
                    IF (DIV.GT.1.E-6)
                   *FLOW=(T24FP*(X(110)+FP100(4))-X(106)*X(28))/DIV
              C     ****************************************************************
              C
(I=103,105-120).
              C     TRANSFER OF P FROM GREEN MATERIAL TO A.G. STANDING DEAD (NON-WOODY)
                    IF(X(I-82)          .LE.1.E-05) GO TO 31005
                    FLOW=P2160(I-102)/X(I-82)*X(I)*FP 120(I-102)
                    GO TO 31006
              31005 FLOW=0.
              31006 CONTINUE
              C
(120-123).
                    FLOW=0.
                    IF(X(600).GT.1.E-05)  FLOW=D6064*X(120)/X(600)
              C
              C
              C
(I=108,109-120).
              C     TRANSFER OF P FROM A.G. RESERVES OF PERENNIALS AND ANNUALS TO A.G.
              C     STANDING DEAD NON-WOODY
                    IF(X(I-82)          .LE.1.E-05)  GO TO 31007
                    FLOW=P2561(I-106)/X(I-82)*X(I)*FP 120(I-103)
                    GO TO 31008
              31007 FLOW=0.
              31008 CONTINUE
              C     ****************************************************************
              C
(106-121).
              C     TRANSFER OF P FROM GREEN CRYPTOGAMS TO A.G. STANDING DEAD (CRYPTOGAMS)
                    IF(X(24)            .LE.1.E-05) GO TO 31009
                    FLOW=P2160(4)/X(24)*X(106)*FP 121(1)
                    GO TO 31010
              31009 FLOW=0.
              31010 CONTINUE
              C
(121-126).
                    FLOW=0.
                    IF(T690 .GT.1.E-05) FLOW=D6973*X(121)/T690
                    F1216=FLOW
              C
              C     ****************************************************************
(110-121).
```

```
C      TRANSFER OF P IN A.G. RESERVES TO STANDING DEAD (CRYPTOGAMS)
       IF(X(28)            .LE.1.E-05)  GO TO 31011
       FLOW=P2561(4)/X (28)*X (110)*FP 121(2)
       GO TO 31012
31011 FLOW=0.
31012 CONTINUE
C
C      ****************************************************************
(107-119).
C      TRANSFER OF P FROM A.G. WOODY RESERVES TO STANDING DEAD (WOODY)
       IF(X(25)            .LE.1.E-05) GO TO 31013
       FLOW=P2561(1)/X(25)*X(107) *FP120(4)
       GO TO 31014
31013 FLOW=0.
31014 CONTINUE
C
(119-122).
       FLOW=0.
       IF(X(610).GT.1.E-05) FLOW=D6163*X(119)/X(610)
C      ****************************************************************
C
(111-124).
C      TRANSFER OF P FROM B.G. SHRUBS TO B.G. DEAD (CF C FLOWS 29-68)
       IF(X(29) .LE.1.E-05) GO TO 31015
       FLOW=P2968(1)*X(111)/X(29)*FP111(1)
       GO TO 31016
31015 FLOW=0.
31016 CONTINUE
C      ****************************************************************
(112-125).
C      TRANSFER OF P IN B.G. RESERVES OF PERENNIALS TO B.G. DEAD ROOTS
C      (CF CARBON FLOW 30-67)
       IF(X(30)      .LE.1.E-05) GO TO 31017
       FLOW=P2968(2)*X(112)/X(30)*FP111(2)
       GO TO 31018
31017 FLOW=0.
31018 CONTINUE
C      ****************************************************************
(I=115,118-125).
       IF(X(I-82) .LE.1.E-05) GO TO 31019
       FLOW=P3367(I-114)*X(I)/X(I-82)*FP111(I-112)
       GO TO 31020
31019 FLOW=0.
31020 CONTINUE
       J=54
(I=124,125-126).
C      ****************************************************************
C      TRANSFERS OF P FROM B.G. TO HUMUS (CF CARBON FLOWS 68,67-73)
       J=J+2
       K=(I-J)*10
       T681=X(K+1)+X(K+2)+X(K+3)
       IF(T681             .LE.1.E-05) GO TO 31021
       FLOW=D6773(I-123)*X(I)/T681
       GO TO 31022
31021 FLOW=0.
31022 CONTINUE
C      ****************************************************************
(I=122,123-126).
C      TRANSFERS OF P FROM LITTER TO HUMUS      (CF CARBON FLOWS 62,63-73)
       FLOW=0.
       K=(I-59)*10
       T631=X(K+1)+X(K+2)+X(K+3)
       IF(T631.GT.1.E-05) FLOW=D6373(I-121)*X(I)/T631
C      ****************************************************************
(126-127).
C      TRANSFER OF P OUT OF HUMUS TO NON-AVAILABLE P POOL
       IF(X(730)  .LE.1.E-05) GO TO 31025
       FLOW=D73*X(126)/X(730)
       GO TO 31026
31025 FLOW=0.
```

```
31026 CONTINUE
      F1267=FLOW
C
C     ****************************************************************
C
C     ****************************************************************
C

      FUNCTION ALINT(TABX,TABY,N,XVAL)
C     LINEAR INTERPOLATION ROUTINE
C     TABX MUST BE A CONTINUOUSLY ASCENDING ARRAY
C     IF XVAL IS OUT OF RANGE OF TABX THE FIRST OR LAST ENTRY IN TABY WILL
C     BE RETURNED
      DIMENSION TABX(1),TABY(1)
      IF(XVAL.LE.TABX(1)) GO TO 20
      IF(XVAL.GE.TABX(N)) GO TO 30
      DO 10 I=2,N
      IF(XVAL.LE.TABX(I)) GO TO 15
   10  CONTINUE
   15 CONTINUE
      ALINT=(XVAL-TABX(I-1))*(TABY(I)-TABY(I-1))/(TABX(I)-TABX(I-1))
     1+TABY(I-1)
      RETURN
   20 ALINT=TABY(1)
      RETURN
   30 ALINT=TABY(N)
      RETURN
      END

      EVENT TNORM
      ATMIN = -14.0
      ATMAX = 10.0
      ATSMX(1)=11.0
      ATSMX(2)=9.5
      ATSMX(3)=9.0
      ATSMN(1)=-5.0
      ATSMN(2)=-4.0
      ATSMN(3)=-2.0
      RETURN
      END

      EVENT COLD
      ATMIN=-25.0
      ATMAX = 5.0
      ATSMX(1)=5.0
      ATSMX(2)=4.0
      ATSMX(3)=3.0
      ATSMN(1)=-12.0
      ATSMN(2)=-8.0
      ATSMN(3) = -4.0
      RETURN
      END

      EVENT WARM
      ATMIN = -5.0
      ATMAX = 20.0
      ATSMX(1)=18.0
      ATSMX(2)=15.0
      ATSMX(3)=12.0
      ATSMN(1)=-2.0
      ATSMN(2)=-1.5
      ATSMN(3)=-1.0
      RETURN
      END

      EVENT WET
      ATS3(1) = 220.0
      ATS4(1) = 225.0
      ATS1(1) = 230.0
      ATS2(1) = 235.0
      ATS3(2) = ATS3(3) = 230.0
      ATS4(2) = ATS4(3) = 235.0
      ATS1(2) = ATS1(3) = 240.0
      ATS2(2) = ATS2(3) = 245.0
      RETURN
      END

      EVENT DRY
      ATS3(1)=ATS3(2)=ATS3(3)=150.0
      ATS4(1)=ATS4(2)=ATS4(3)=180.0
      ATS1(1)=ATS1(2)=ATS1(3)=250.0
      ATS2(1)=ATS2(2)=ATS2(3)=260.0
      RETURN
      END
```

```
      EVENT WNORM
      ATS3(1)=150.0
      ATS3(2)=170.0
      ATS3(3) = 200.0
      ATS4(1)=195.0
      ATS4(2)=210.0
      ATS4(3) = 220.0
      ATS1(1)=230.0
      ATS1(2)=240.0
      ATS1(3)=250.0
      ATS2(1)=250.0
      ATS2(2)=ATS2(3)=260.0
      RETURN
      END

      SUBROUTINE START
      PRINT 20000
20000 FORMAT(1H1,25X,*TOTAL PRODUCER MODEL (GROUP IV-P)*/
     1 1H0,25X,*SIMULATION OF HARDANGERVIDDA, NORWAY*)
C
C ... INITIALIZE THE FACTOR (PTN) WHICH ASSURES THAT THE STRUCTURAL BIOMASS

C     IS NOT REMOVED FROM THE ABOVE-GROUND GREEN DURING TRANSLOCATION.
C
      DO 20003 PK=1,4
      PI=PK+20
      PXTRL(PK)=PTRN(PK)*X(PI)
20003 PTN(PK)=PTRN(PK)
      ATYD  =  X(3)
      DO3I=1,3
      ASMAX(I)=ASMAX(I)*ASODP*ASP(I)
    3 ASMIN(I)=ASMIN(I)*ASODP*ASP(I)
C     INITIALIZE AMOUNT OF P IN ALL COMPARTMENTS
C     FPP(I=1,16)  INITIAL CONC. OF P IN PLANT COMPARTMENTS IN PER CENT
      DO 20004 I=1,16
      J=I+102
      K=I+20
20004 X(J)=X(K)*FPP(I)/100.
C     FNN(I=1,16)  INITIAL CONC. OF N IN PLANT COMPARTMENTS
C     INITIALIZE AMOUNT OF N IN ALL COMPARTMENTS
      DO 20006 I=1,16
      J=I+202
      K=I+20
20006 X(J)=X(K)*FNN(I)/100.
      RETURN
      END

      SUBROUTINE PFLOW(A,B,C,D,G,J)
      DIMENSION A(4),B(4),C(3),   IZ(3),F(9),G(3)
      DO 10 I=1,3
   10 IZ(I)=G(I)=0.
      NZ=0
      IF(B(1).LE.1.E-7) GO TO 20
      NZ=NZ+1
      IZ(NZ)=1
   20 IF(B(2).LE.1.E-7) GO TO 30
      NZ=NZ+1
      IZ(NZ)=2
   30 IF(B(3).LE.1.E-7) GO TO 40
      NZ=NZ+1
      IZ(NZ)=3
   40 CONTINUE
      NZ1=NZ+1
      GO TO(50,51,52,53)NZ1
   51 K=IZ(1)   $ BC=B(K)*C(K)
      G(K)=((A(4)+D)*BC-A(K)*B(4))/(B(4)+BC)
      RETURN
   52 K=IZ(1)
      L=IZ(2)
      AB1=B(K)*C(K)
      AB2=B(L)*C(L)
      CC=A(4)+D
      F(1)=AB1+B(4)
      F(3)=AB1
      F(2)=AB2
```

```
      F(4)=AB2+B(4)
      G(1)=CC*AB1-A(K)*B(4)
      G(2)=CC*AB2-A(L)*B(4)
      CALL SIMQ(F,G,NZ,KS)
      IF(KS.EQ.1)WRITE(6,4000)J
 4000 FORMAT(///,*   SINGULAR MATRIX  J = *,I3,///)
      RETURN
   53 AB1=B(1)*C(1)
      AB2=B(2)*C(2)
      AB3=B(3)*C(3)
      CC=A(4)+D
      F(1)=AB1+B(4)
      F(2)=AB2
      F(3)=AB3
      F(4)=AB1
      F(5)=AB2+B(4)
      F(6)=AB3
      F(7)=AB1
      F(8)=AB2
      F(9)=AB3+B(4)
      G(1)=AB1*CC-A(1)*B(4)
      G(2)=AB2*CC-A(2)*B(4)
      G(3)=AB3*CC-A(3)*B(4)
      CALL SIMQ(F,G,NZ,KS)
      IF(KS.EQ.1)WRITE(6,4000)J
   50 CONTINUE
      RETURN
      END

      SUBROUTINE CYCL1
C ... PK IS AN INDEX FOR EACH OF THE FOUR SPECIES
C     PK=1 FOR WOODY PLANTS
C     PK=2 FOR PERENNIAL PLANTS
C     PK=3 FOR ANNUAL PLANTS
C     PK=4 FOR CRYPTOGENS
      DO 20050 PK=1,4
      PI=PK+20
C
C ... DETERMINE THE FACTOR DUE TO AIR TEMPERATURE [X(3)] FOR NET ASSIMILATION
C
      IF(X(3).GE.PTO1(PK)) GO TO 20001
      PFT(PK)=(X(3)-PTMN(PK))/(PTO1(PK)-PTMN(PK))
      GO TO 20003
20001 IF(X(3).GT.PTO2(PK)) GO TO 20002
      PFT(PK)=1.0
      GO TO 20003
20002 PFT(PK)=(PTMX(PK)-X(3))/(PTMX(PK)-PTO2(PK))
C
C ... CALCULATE WEIGHTED NORMALIZED WATER CONTENT FROM VOLUMETRIC WATER CONTENT
C
20003 PWTR=0.0
      DO 20024 PJ=1,3
      PWW(PJ)=(((X(PJ+9))/(ASODP*ASP(PJ)))-ASWP(PJ))/(ASFC(PJ)-ASWP(PJ))
20024 PWTR=PWTR+PROOT(PK,PJ)*PWW(PJ)
C
C ... DETERMINE FACTOR DUE TO SOIL WATER[X(10),X(11),X(12)] FOR NET ASSIMILATION
C
      PFW(PK)=(PC(PK)*PWTR)/(PC(PK)*PWTR+(1.0-PWTR)*(1.0-PC(PK)))
      IF(PWTR.LE.0.)PFW(PK)=0.
C
C ... DETERMINE THE FACTOR DUE TO RADIATION [X(2)] FOR NET ASSIMILATION
C
      PFR(PK)=1.0
      IF(X(2).LT.PRS(PK)) PFR(PK)=(X(2)-PRC(PK))/(PRS(PK)-PRC(PK))
C
C ... DETERMINE THE FACTOR DUE TO SHADING [X(PI)] FOR NET ASSIMILATION
C
      PFS(PK)=1.0
      IF(X(PI).GT.PXS(PK)) PFS(PK)=PXS(PK)/X(PI)
C
C ... CALCULATE FACTOR DUE TO AIR TEMPERATURE [X(3)] FOR TRANSLOCATION
C
      IF(X(3).GT.PTMNR(PK)) GO TO 20004
      PHT(PK)=0.0
      GO TO 20006
20004 IF(X(3).GT.PTMXR(PK)) GO TO 20005
      PHT(PK)=(X(3)-PTMNR(PK))/(PTMXR(PK)-PTMNR(PK))
      GO TO 20006
20005 PHT(PK)=1.0
C
C ... CALCULATE FACTOR DUE TO SOIL WATER [X(10),X(11),X(12)] FOR TRANSLOCATION
C
```

```
20006 IF(PWTR.GT.PWMNR(PK)) GO TO 20007
      PHW(PK)=0.0
      GO TO 20009
20007 IF(PWTR.GT.PWMXR(PK)) GO TO 20008
      PHW(PK)=(PWTR-PWMNR(PK))/(PWMXR(PK)-PWMNR(PK))
      GO TO 20009
20008 PHW(PK)=1.0
C ... CALCULATE FACTOR DUE TO X(PI) FOR TRANSLOCATION DURING ACTIVATION STAGE
20009 PHX21(PK)=1.0
      IF(X(PI).LE.PX21L(PK)) GO TO 20010
      PHX21(PK)=(PX21Z(PK)-X(PI))/(PX21Z(PK)-PX21L(PK))
      IF(X(PI).LE.PX21Z(PK)) GO TO 20010
      PHX21(PK)=0.0
C
C ... CALCULATE FACTOR DUE TO X(PI) FOR TRANSLOCATION DURING GROWTH STAGE
C
20010 PKX21(PK) = 1.0 - PHX21(PK)
C
C ... CALCULATE THE CHANGE IN CONDITIONS FOR NET ASSIMILATION FROM THE LAST
C     TIME STEP TO THE CURRENT TIME
C
      PODF(PK)=PNDF(PK)
      PNDF(PK)=PFT(PK)*PFW(PK)*PFR(PK)*PFS(PK)
      IF(PFT(PK).LT.0.0.OR.PFR(PK).LT.0.0.OR.PFW(PK).LT.0.0)

      1 PNDF(PK)=-1.0*ABS(PNDF(PK))
       PDF(PK)=PODF(PK)-PNDF(PK)
       IF(PODF(PK).EQ.0.0.AND.PNDF(PK).EQ.0.0) PDF(PK)=0.0
C
C ... CALCULATE FACTOR DUE TO KD FOR TRANSLOCATION DURING THE GROWING STAGE
C
C ... PKD = (PKDT + PKDW + PKDS + PKDR) / NI, WHERE NI IS NO. OF NON-
C ... ZERO CONTRIBUTING FACTORS
C
C ... PKD = 0 IF NI = 0
C
C ... PKD = 1 IF ANY OF THE FOUR FACTORS IS 1
C
C ... PKD = 0 IF X(3) .LT. PKDMN (CUTOFF TEMPERATURE)
C
C ... CALCULATE FACTOR DUE TO TEMPERATURE FOR PKD
C
      NI=0
      PKDT(PK) = 0.0
      IF (X(3) .GE. PKDMN)   GO TO 20028
      ATYD = X(3)
      GO TO 20036
20028 IF (X(3) .GT. ATYD)  GO TO 20030
      ATYD = X(3)
      PKDT(PK) = 1.0
      IF(X(3) .LE. PKDT1(PK))  GO TO 20018
      PKDT(PK) = 0.0
      IF(X(3) .GE. PKDT2(PK))  GO TO 20030
      PKDT(PK) = (PKDT2(PK) - X(3)) /(PKDT2(PK) - PKDT1(PK))
      NI=NI+1
C
C ... CALCULATE FACTOR DUE TO WATER FOR PKD
C
20030 PKDW(PK) = 1.0
      ATYD = X(3)
      IF (PWTR .LE. PKDW1(PK))  GO TO 20018
      PKDW(PK) = 0.0
      IF(PWTR .GE. PKDW2(PK))  GO TO 20032
      PKDW(PK) = (PKDW2(PK) -PWTR) / (PKDW2(PK) - PKDW1(PK))
      NI=NI+1
C
C ... CALCULATE FACTOR DUE TO SHADING FOR PKD
C
20032 PKDS(PK) = 0.0
      IF (X(PI) .LE. PKDS1(PK))  GO TO 20034
      PKDS(PK) = 1.0
      IF(X(PI) .GE. PKDS2(PK))   GO TO 20018
      PKDS(PK) = (X(PI) - PKDS1(PK)) / (PKDS2(PK) -PKDS1(PK))
      NI=NI+1
C
C ... CALCULATE FACTOR DUE TO RADIATION FOR PKD
C
20034 PKDR(PK) = 1.0
```

```
      IF(X(2) .LE. PKDR1(PK))  GO TO 20018
      PKDR(PK) = 0.0
      IF(X(2) .GE. PKDR2(PK))  GO TO 20036
      PKDR(PK) = (PKDR2(PK) - X(2)) / (PKDR2(PK) - PKDR1(PK))
      NI=NI+1
C
C ... CALCULATE PKD AS SHOWN ABOVE
C
20036 PKD(PK) = 0.0
      IF (NI.GT.0)
     *PKD(PK) = (PKDT(PK) + PKDW(PK) + PKDS(PK) + PKDR(PK))/NI
      GO TO 20011
C
20018 PKD(PK)=1.0
      ATYD = X(3)
C
C ... CALCULATE MORTALITY FACTOR DUE TO TEMPERATURE FOR GREEN
C
20011 PMT(PK)=1.0
      IF(X(3).LE.PTD1(PK).OR.X(3).GE.PTD4(PK)) GO TO 20012
      PMT(PK)=(PTD2(PK)-X(3))/(PTD2(PK)-PTD1(PK))
      IF(X(3).LE.PTD2(PK)) GO TO 20012
      PMT(PK)=0.0
      IF(X(3).LE.PTD3(PK)) GO TO 20012
      PMT(PK)=(X(3)-PTD3(PK))/(PTD4(PK)-PTD3(PK))
C
C ... CALCULATE MORTALITY FACTOR DUE TO SOIL WATER FOR GREEN
20012 PMW(PK)=1.0
      IF(PWTR.LE.PWD1(PK)) GO TO 20013
      PMW(PK)=(PWD2(PK)-PWTR)/(PWD2(PK)-PWD1(PK))
      IF(PWTR.LE.PWD2(PK)) GO TO 20013
      PMW(PK)=0.0
      IF(PWTR.LE.PWD3(PK)) GO TO 20013
      PMW(PK)=PWLD(PK)
C
C ... CALCULATE MORTALITY FACTOR DUE TO SHADING FOR GREEN
C
20013 PMS(PK)=0.0
      IF(X(PI).LE.PXM(PK)) GO TO 20014
      PMS(PK)=PMGR(PK)
      IF(X(PI).GE.PXS(PK)) GO TO 20014
      PMS(PK)=PMGR(PK)*(X(PI)-PXM(PK))/(PXS(PK)-PXM(PK))
C
C ... CALCULATE FACTOR DUE TO X(PJ) FOR DEATH OF ROOTS
C
20014 PI=PK+28
      PJ=PK+32
      PKRT(PK)=0.0
      IF(X(PJ).GT.PRRR(PK)*X(PI)) PKRT(PK)=1.0
C
C ... CALCULATE THE WEIGHTED AVERAGE SOIL TEMPERATURE
C
      PST=0
      DO 20015 PJ=1,3
20015 PST=PST+X(PJ+3)*PROOT(PK,PJ)
C
C ... CALCULATE FACTOR DUE TO SOIL TEMPERATURE FOR DEATH OF ROOTS
C
      PMRT(PK)=1.0
      IF(PST.LE.PTD1(PK).OR.PST.GE.PTD4(PK)) GO TO 20016
      PMRT(PK)=(PTD2(PK)-PST)/(PTD2(PK)-PTD1(PK))
      IF(PST.LE.PTD2(PK)) GO TO 20016
      PMRT(PK)=0.0
      IF(PST.LE.PTD3(PK)) GO TO 20016
      PMRT(PK)=(PST-PTD3(PK))/(PTD4(PK)-PTD3(PK))
C
C ... THE FACTOR DUE TO SOIL WATER FOR DEATH OF ROOTS IS SAME AS FOR DEATH OF
C     GREENS
C
20016 PMRW(PK)=PMW(PK)
20050 CONTINUE
C     INITIALIZE THE FLOW FN200(I)
      DO 60000 I=1,4
      FP100(I)=0.
60000 FN200(I)=0.0
C
      T630 = X(631) + X(632) + X(633)
C
      T640 = X(641) + X(642) + X(643)
```

```
C
      T670 = X(671) + X(672) + X(673)
C
      T680 = X(681) + X(682) + X(683)
C
      T690 = X(691) + X(692) + X(693)
      RETURN
      END

      SUBROUTINE CYCL2
C
C ... UPDATE THE AMOUNT OF TRANSLOCATABLE MATERIAL AND THE FACTOR FOR
C     THE TRANSLOCATABLE MATERIAL FROM ABOVE-GROUND LIVE GREEN
C
      DO 20001 PK=1,4
      PI=PK+20
      PXTRL(PK)=PXTRL(PK)+PTRN(PK)*P121(PK)-PTRN(PK)*P2160(PK)-P2125(PK)
     1   -P2129(PK)-P2133(PK)
      IF(X(PI).EQ.0.0) GO TO 20001
      PTN(PK)=PXTRL(PK)/X(PI)
      IF (PTN (PK) .LE. 0.0)    PTN(PK) = 0.0
20001 CONTINUE
      RETURN
      END
```

RESULTS

A model of the type described is designed to provide a basis for inter-site comparisons in terms of both overall response and in terms of the magnitude of the various processes on which the model operates. The initial steps in the use of the model are concerned with tuning it to mimic as far as possible the known behavior at a given site. In this process, while good information is available on some flows, some responses, and some state variables, there are usually many unknowns for which "educated" guesses are required. When the step is completed, i.e., when the model gives "acceptable" output, the total set of parameters can be considered in terms of their biological reality and meaning. Furthermore, they can provide a basis for experimentation and data collection from which improvement in understanding and in the model itself can be made. A well-tested model has the additional advantage of having predictive value.

In the present study a start on these series of steps was made. The model was tuned for two Norwegian plant communities, a reindeer lichen community and a perennial grass community. The parameters used for these runs of the model are shown in Tables 2 and 3. An initial between-site comparison has been made, but no restructuring of the model has been attempted.

Time trends for some state variables obtained during the final runs of the model are presented in Fig. 29 through 42. Reliable information was available on site and soil characteristics, biomass changes, and plant nutrient content, but there was limited information on many other aspects, especially on aspects of decomposer activity. As might be expected, many of the actual process parameters on which the model runs were unknown at the outset and their final values were arrived at by testing a range of possible values considered to represent biological, reasonable limits.

Table 2. Simulation control parameters for abiotic, carbon (producer), and decomposer submodels; lichens and shrubs at a lichen heath.

```
SIMCOMP VERSION 3.0          PARAMETER VALUES

                         - SIMULATION CONTROL PARAMETERS -

                            TIME   = INDEFINITE
                            TSTRT  =   1.00000000
                            TEND   =   720.000000
                            DT     =   1.00000000
                            DTPR   =   30.0000000
                            DTPL   =           .0
                            DTFL   =   30.0000000

                              - STATE VARIABLES -

X(  1-  2) =            0   X(  3) = -12.0000000   X(  4) = -5.00000000   X(  5) = -4.00000000
   X(  6) = -2.00000000    X( 10) =  1.00000000   X( 11) =  8.00000000   X( 12) =  9.00000000
   X( 21) =  20.0000000  X( 22- 23) =          0   X( 24) =  150.000000   X( 25) =  25.0000000
X( 26- 27) =            0   X( 28) =  50.0000000   X( 29) =  60.0000000 X( 30- 32) =          0
   X( 33) =  50.0000000  X( 34- 36) =          0 X( 60- 61) =          0 X( 63- 64) =          0
X( 67- 69) =            0   X( 80) =           0
                           X(600) =  5.00000000   X(610) =  5.00000000   X(631) =  1.66700000
   X(632) =  3.33300000    X(633) =  5.00000000 X(641-643) = 15.0000000  X(671) =  20.0000000
   X(672) =  28.0000000    X(673) =  32.0000000   X(681) =  10.0000000   X(682) =  20.0000000
   X(683) =  30.0000000    X(691) =  20.0000000   X(692) =  50.0000000   X(693) =  80.0000000
   X(730) =  10000.0000

                            - USER DEFINED VARIABLES -

ARMAX =  400.000000          ARMIN =  25.0000000          ASRD(1) =  .800000000         ASRD(2-3) =  1.50000000
ASFC(1) =  .900000000E-01    ASFC(2) =  .700000000E-01    ASFC(3) =  .500000000E-01    ASLAG(1) =  25.0000000
ASLAG(2) =  40.0000000       ASLAG(3) =  50.0000000       ASMAX(1) =  .120000000       ASMAX(2) =  .900000000E-01
ASMAX(3) =  .600000000E-01   ASMIN(1-3) =  .100000000E-01 ASODP =  250.000000         ASP(1) =  .400000000E-01
ASP(2) =  .360000000         ASP(3) =  .600000000         ASWP(1) =  .200000000E-01    ASWP(2-3) =  .100000000E-01
ATLAG =  20.0000000          ATMAX =  10.0000000          ATMIN = -14.0000000          ATSMN(1) = -5.00000000
ATSMN(2) = -4.00000000       ATSMN(3) = -2.00000000       ATSMX(1) =  11.0000000       ATSMX(2) =  9.50000000
ATSMX(3) =  9.00000000       ATS1(1) =  230.000000        ATS1(2) =  240.000000        ATS1(3) =  250.000000
ATS2(1) =  250.000000        ATS2(2-3) =  260.000000      ATS3(1) =  150.000000        ATS3(2) =  170.000000
ATS3(3) =  200.000000        ATS4(1) =  195.000000        ATS4(2) =  210.000000        ATS4(3) =  220.000000
DHCHR =  4.10000000          DHCHU =  4.00000000          DHCWR =  4.00000000          DH64X(1) =  3.00000000
DH64X(2) =  7.00000000       DH64X(3) =  9.00000000       DH64X(4) =  10.0000000       DH64Y(1) =           0
DH64Y(2-3) =  1.00000000     DH64Y(4) =           0       DMAXR(1) =  .350000000E-01   DMAXR(2) =  .200000000E-01
DMAXR(3) =  .100000000E-01   DMAXR(4) =  .200000000E-01   DMAXR(5) =  .500000000E-02   DMAXR(6) =  .100000000E-02
DMAXR(7) =  .470000000E-01   DMAXR(8) =  .280000000E-01   DMAXR(9) =  .190000000E-01   DMAXR(10) =  .180000000E-01
DMAXR(11) =  .900000000E-02  DMAXR(12) =  .300000000E-02  DMAXR(13) =  .100000000E-02  DMAXR(14) =  .300000000E-03
DMAXR(15) =  .100000000E-03  DMXH =  .330000000E-03       DNCC =  .550000000           DNCH =  1.20000000
DNCHR =  1.00000000          DNCHU =  .800000000          DNCW =  1.00000000           DNCWR =  .900000000
DN64X(1) =  .100000000       DN64X(2) =  1.50000000       DN64Y(1) =           0       DN64Y(2) =  1.00000000
DPHCC =  3.70000000          DPHCH =  4.20000000          DPHCW =  4.10000000          DP600(1-3) =  .333300000
DP610(1) =  .166700000       DP610(2) =  .333300000       DP610(3) =  .500000000       DP670(1) =  .250000000
DP670(2) =  .350000000       DP670(3) =  .400000000       DP680(1) =  .166700000       DP680(2) =  .333300000
DP680(3) =  .500000000       DP690(1) =  .333400000       DP690(2-3) =  .333300000     DRESP(1-15) =          0
DT64X(1) = -2.00000000       DT64X(2) =  12.0000000       DT64Y(1) =           0       DT64Y(2) =  1.00000000
DW64X(1) =  .340000000E-01   DW64X(2) =  .480000000E-01   DW64X(3) =  .118000000       DW64X(4) =  .146000000
DW64Y(1) =           0       DW64Y(2-3) =  1.00000000     DW64Y(4) =           0       D600(1) =  .100000000E-02
D600(2) =  .400000000E-03    D600(3) =  .150000000E-01    D600(4) =  .400000000E-03    D6064 =           0
D610(1-4) = INDEFINITE       D6163 =           0          D6373(1-2) =           0     D6773(1-2) =          0
D6973 =           0          D73 =           0
                             PACRA(1-3) =  .800000000E-03 PACRA(4) =           0       PACRR(1-3) =  .500000000E-0
PACRR(4) =           0       PACTA(1-4) =  .800000000E-03 PACTR(1-3) =  .150000000E-02 PACTR(4) =           0
PC(1-3) =  .900000000        PC(4) =  .800000000          PCNMN(1) =           0       PCNMN(2) = -2.00000000
PCONS =           0          PCONW =           0          PCRDR(1-3) =  .100000000E-02 PCRDR(4) =           0
PDAR(1-3) =  .200000000E-03  PDAR(4) =  .140000000E-02    PDRR(1-3) =  .500000000E-06  PDRR(4) =           0
PDF(1-4) =           0       PDLG(1-3) =  .400000000E-01  PDLG(4) =  .650000000E-03    PFR(1-4) =           0
PFS(1-4) =           0       PFT(1-4) =           0       PFW(1-4) =           0       PHT(1-4) =           0
PHW(1-4) =           0       PHX21(1-4) =           0     PI = INDEFINITE              PJ = INDEFINITE
PK = INDEFINITE              PKD(1-4) =           0       PKDMN = -8.00000000          PKDR(1-4) = INDEFINITE
PKDR1(1-4) =  150.000000     PKDR2(1-4) =  250.000000     PKDS(1-4) = INDEFINITE       PKDS1(1-3) =  50.0000000
PKDS1(4) =  300.000000       PKDS2(1-3) =  150.000000     PKDS2(4) =  350.000000       PKDT(1-4) = INDEFINITE
PKDT1(1-3) = -5.00000000     PKDT1(4) = -3.00000000       PKDT2(1-3) =  4.00000000     PKDT2(4) =           0
PKDW(1-4) = INDEFINITE       PKDW1(1-4) =           0     PKDW2(1-3) =  .300000000     PKDW2(4) =  .400000000
PKM(1-4) =           0       PKRT(1-4) =           0      PKX21(1-4) =           0     PMGR(1-3) =  .250000000E-01
PMGR(4) =  .700000000E-02    PMRT(1-4) =           0      PMRW(1-4) =           0      PMS(1-4) =           0
PMT(1-4) =           0       PMW(1-4) =           0       PNDF(1-4) =           0      PODF(1-4) =           0
PRC(1-4) =  40.0000000       PRER(1-4) =  .300000000E-03  PROOT(1,1) =  .500000000E-01 PROOT(2,1-3,1) =
PROOT(4,1) =  1.00000000     PROOT(1,2) =  .700000000     PROOT(2,2-4,2) =           0 PROOT(1,3) =  .250000000
PROOT(2,3-4,3) =           0 PRRO(1-3) =  .100000000E-02  PRRO(4) =  .800000000E-03    PRRR(1-3) =  .300000000
PRRR(4) =           0        PRS(1-4) =  400.000000       PR20(1-3) =  .200000000E-01  PR20(4) =  .550000000E-02
```

```
PST(1) =                0        PST(2-4) = INDEFINITE          PSTMA(1-3) =  .100000000         PSTMA(4) =  .700000000E-02
PSTMB(1-3) =  .600000000         PSTMB(4) =                0    PTD1(1-3) = -60.0000000          PTD1(4) = -10.0000000
PTD2(1-3) = -3.00000000          PTD2(4) = -5.00000000          PTD3(1-3) =  30.0000000          PTD3(4) =  20.0000000
PTD4(1-3) =  36.0000000          PTD4(4) =  30.0000000          PTMN(1-3) =                0     PTMN(4) = -3.00000000
PTMNR(1-3) = -3.00000000         PTMNR(4) = -5.00000000         PTMX(1-3) =  30.0000000          PTMX(4) =  20.0000000
PTMXR(1-3) =  5.00000000         PTMXR(4) =  7.00000000         PTN(1-4) =                0      PTRMA(1-4) =  .100000000E-01
PTRMB(1-3) =  .700000000E-01     PTRMB(4) =                0    PTRN(1-3) =  .700000000          PTRN(4) =  .500000000
PTRR(1-3) =  .100000000E-01      PTRR(4) =                0     PTO1(1-4) =  10.0000000          PTO2(1-3) =  18.0000000
PTO2(4) =  16.0000000            PWD1(1-3) = -.100000000        PWD1(4) = -.100000000E-01        PWD2(1-3) =  .100000000
PWD2(4) =  .300000000E-01        PWD3(1-3) =  1.60000000        PWD3(4) =  1.20000000            PWLD(1-3) =  .500000000E-01
PWLD(4) =  .500000000E-02        PWMNR(1-4) =  .200000000       PWMXR(1-3) =  .600000000         PWMXR(4) =  .800000000
PWTR =                0          PWW(1-3) =                0    PXM(1-3) =  60.0000000           PXM(4) =  150.000000
PXS(1-3) =  200.000000           PXS(4) =  250.000000           PXTRL(1-4) =                0    PX21L(1-3) =  15.0000000
PX21L(4) =  170.000000           PX217(1-3) =  25.0000000       PX217(4) =  200.000000           P121(1-4) =                0
P2125(1-4) =                0    P2129(1-4) =                0  P2133(1-4) =                0    P2160(1-4) =                0
P2561(1-4) =                0    P2968(1-4) =                0  P3367(1-4) =                0    P6373(1-3) =                0
P6473(1-3) =                0    P6473(4) = INDEFINITE          P6773(1-3) =                0    P6773(4) = INDEFINITE
P6873(1-3) =                0    P6873(4) = INDEFINITE          P6973(1-3) =                0    P6973(4) = INDEFINITE
TARM =  255.000000               TDEN(1-3) = INDEFINITE         TDEPH(1-3) = INDEFINITE          TDET(1-3) = INDEFINITE
TDEW(1-3) = INDEFINITE           T106 = INDEFINITE              T24 =  200.000000                T630 =                0
T640 =                0          T670 =                0        T680 =                0          T690 =  150.000000
WATER = INDEFINITE
```

Table 3. Simulation control parameters for abiotic, carbon (producer), and decomposer submodels; perennials at a dry meadow.

```
SIMCOMP VERSION 3.0          PARAMETER VALUES

                         - SIMULATION CONTROL PARAMETERS -

                           TIME  = INDEFINITE
                           TSTRT =  1.00000000
                           TEND  =  720.000000
                           DT    =  1.00000000
                           DTPR  =  30.0000000
                           DTPL  =           0
                           DTFL  =  30.0000000

                              - STATE VARIABLES -

X(  1-  6) =          0   X( 10- 12) =           0   X( 21) =           0   X( 22) =  5.00000000
X( 23- 25) =          0   X( 26) =  25.0000000   X( 27- 29) =           0   X( 30) =  80.0000000
X( 31- 33) =          0   X( 34) =  160.000000   X( 35- 36) =           0   X( 60- 61) =           0
X( 63- 64) =          0   X( 67- 69) =           0   X( 80) =           0
                                                   X(600) =  40.0000000   X(610) =           0
X(631-633) =          0   X(641) =  25.0000000   X(642) =  16.7000000   X(643) =  8.30000000
X(671) =  33.6000000   X(672) =  40.8000000   X(673) =  45.6000000   X(681-683) =           0
X(691-693) =          0   X(730) =  30000.0000

                         - USER DEFINED VARIABLES -

ARMAX =  400.000000          ARMIN =  25.0000000          ASBD(1) =  .800000000        ASBD(2-3) =  1.50000000
ASFC(1) =  .200000000        ASFC(2) =  .160000000        ASFC(3) =  .200000000        ASLAG(1) =  25.0000000
ASLAG(2) =  40.0000000       ASLAG(3) =  50.0000000       ASMAX(1) =  .200000000       ASMAX(2) =  .160000000
ASMAX(3) =  .200000000       ASMIN(1) =  .110000000       ASMIN(2) =  .100000000       ASMIN(3) =  .120000000
ASODP =  500.000000          ASP(1) =  .300000000         ASP(2) =  .400000000         ASP(3) =  .300000000
ASWP(1) =  .100000000        ASWP(2) =  .800000000E-01    ASWP(3) =  .100000000        ATLAG =  20.0000000
ATMAX =  9.00000000          ATMIN = -11.0000000          ATSMN(1-3) = -.500000000     ATSMX(1) =  10.5000000
ATSMX(2) =  9.00000000       ATSMX(3) =  8.50000000       ATS1(1) =  240.000000        ATS1(2-3) =  250.000000
ATS2(1) =  250.000000        ATS2(2-3) =  260.000000      ATS3(1) =  165.000000        ATS3(2) =  180.000000
ATS3(3) =  210.000000        ATS4(1-2) =  220.000000      ATS4(3) =  230.000000        DHCHR =  5.50000000
DHCHU =  5.30000000          DHCWR =  5.30000000          DH64X(1) =  1.00000000       DH64X(2) =  7.00000000
DH64X(3) =  9.00000000       DH64X(4) =  10.0000000       DH64Y(1) =           0       DH64Y(2-3) =  1.00000000
DH64Y(4) =           0       DMAXR(1-3) =  .470000000E-01  DMAXR(4) =  .600000000E-01  DMAXR(5) =  .400000000E-01
DMAXR(6) =  .300000000E-01   DMAXR(7) =  .600000000E-01   DMAXR(8) =  .400000000E-01   DMAXR(9) =  .300000000E-01
DMAXR(10) =  .470000000E-02  DMAXR(11) =  .440000000E-02  DMAXR(12) =  .438000000E-02  DMAXR(13) =  .600000000E-01
DMAXR(14) =  .400000000E-01  DMAXR(15) =  .300000000E-01  DMXH =  .700000000E-03    DNCC =           0
DNCH =  1.70000000           DNCHR =  1.60000000          DNCHU =  2.60000000          DNCW =  1.30000000
DNCWR =  1.20000000          DN64X(1) =  .300000000       DN64X(2) =  2.50000000       DN64Y(1) =           0
DN64Y(2) =  1.00000000       DPHCC =           0          DPHCH =  5.80000000          DPHCW =  5.50000000
DP600(1) =  .500000000       DP600(2) =  .333300000       DP600(3) =  .166700000       DP610(1) =  .166700000
DP610(2) =  .333300000       DP610(3) =  .500000000       DP670(1) =  .280000000       DP670(2) =  .340000000
DP670(3) =  .380000000       DP680(1) =  .166700000       DP680(2) =  .333300000       DP680(3) =  .500000000
DP690(1-3) =           0     DRESP(1-15) =           0    DT64X(1) = -1.00000000       DT64X(2) =  10.0000000
DT64Y(1) =           0       DT64Y(2) =  1.00000000       DW64X(1) =  .100000000       DW64X(2) =  .120000000
DW64X(3) =  .260000000       DW64X(4) =  .300000000       DW64Y(1) =           0       DW64Y(2-3) =  1.00000000
DW64Y(4) =           0       D600(1) =  .150000000E-02    D600(2) =  .500000000E-03    D600(3) =  .150000000E-01
D600(4) =  .600000000E-03    D6064 =           0          D610(1-4) = INDEFINITE       D6163 =           0
D6373(1-2) =           0     D6773(1-2) =           0     D6973 =           0          D73 =           0

                                                                                        PACRA(1-4) =  .500000000E-02
PACRB(1-4) =  .150000000E-02 PACTA(1-4) =  .100000000E-01 PACTR(1-4) =  .100000000E-01 PC(1-4) =  .950000000
PCNMN(1) = -2.00000000       PCNMN(2) =           0       PCONS =           0          PCONW =           0
PCRDR(1-4) =  .200000000E-03 PDAR(1-4) =  .800000000E-02  PDRR(1-4) =  .100000000E-03  PDF(1-4) =           0
PDLG(1-4) =  .450000000      PFR(1-4) =           0       PFS(1-4) =           0       PFT(1-4) =           0
PFW(1-4) =           0       PHT(1-4) =           0       PHW(1-4) =           0       PHX21(1-4) =           0
PI = INDEFINITE              PJ = INDEFINITE              PK = INDEFINITE              PKD(1-4) =           0
PKDMN = -8.00000000          PKDR(1-4) = INDEFINITE       PKDR1(1-4) =  150.000000     PKDR2(1-4) =  250.000000
PKDS(1-4) = INDEFINITE       PKDS1(1-4) =  50.0000000     PKDS2(1-4) =  150.000000     PKDT(1-4) = INDEFINITE
PKDT1(1-4) =  1.00000000     PKDT2(1-4) =  5.00000000     PKDW(1-4) = INDEFINITE       PKDW1(1-4) =           0
PKDW2(1-4) =  .400000000     PKM(1-4) =           0       PKRT(1-4) =           0      PKX21(1-4) =           0
PMGR(1-4) =  .650000000E-01  PMRT(1-4) =           0      PMRW(1-4) =           0      PMS(1-4) =           0
PMT(1-4) =           0       PMW(1-4) =           0       PNDF(1-4) =           0      PODF(1-4) =           0
PRC(1-4) =  40.0000000       PRER(1-4) =  .700000000E-03  PROOT(1,1) =  .500000000     PROOT(2,1) =  .700000000
PROOT(3,1-4,1) =           0 PROOT(1,2) =  .350000000     PROOT(2,2) =  .250000000     PROOT(3,2-4,2) =           0
PROOT(1,3) =  .150000000     PROOT(2,3) =  .500000000E-01 PROOT(3,3-4,3) =           0 PRRO(1-4) =  .200000000E-02
PRRR(1-4) =  1.50000000      PRS(1-4) =  400.000000       PR20(1-4) =  .300000000E-01  PST(1) =           0
PST(2-4) = INDEFINITE        PSTMA(1-4) =  .600000000E-01 PSTMB(1-4) =  .500000000E-01 PTD1(1-4) = -1.00000000
PTD2(1-4) =  3.00000000      PTD3(1-4) =  28.0000000      PTD4(1-4) =  35.0000000      PTMN(1-4) =  1.00000000
PTMNR(1-4) =  .500000000     PTMX(1-4) =  26.0000000      PTMXR(1-4) =  6.50000000     PTN(1-4) =           0
PTRMA(1-4) =  .800000000E-02 PTRMB(1-4) =  .500000000E-02 PTRN(1-4) =  .700000000      PTRR(1-4) =  .500000000E-02
PT01(1-4) =  10.0000000      PT02(1-4) =  20.0000000      PWD1(1-4) =           0      PWD2(1-4) =  .100000000
PWD3(1-4) =  1.60000000      PWLD(1-4) =  .500000000E-01  PWMNR(1-4) =  .200000000     PWMXR(1-4) =  .700000000
```

PWTR = 0	PWW(1-3) = 0	PXM(1-4) = 60.0000000	PXS(1-4) = 80.0000000
PXTRL(1-4) = 0	PX21L(1-4) = 10.0000000	PX212(1-4) = 20.0000000	P121(1-4) = 0
P2125(1-4) = 0	P2129(1-4) = 0	P2133(1-4) = 0	P2160(1-4) = 0
P2561(1-4) = 0	P2968(1-4) = 0	P3367(1-4) = 0	P6373(1-3) = 0
P6473(1-3) = 0	P6473(4) = INDEFINITE	P6773(1-3) = 0	P6773(4) = INDEFINITE
P6873(1-3) = 0	P6873(4) = INDEFINITE	P6973(1-3) = 0	P6973(4) = INDEFINITE
TABM = 0	TDEN(1-3) = INDEFINITE	TDEPH(1-3) = INDEFINITE	TDET(1-3) = INDEFINITE
TDEW(1-3) = INDEFINITE	T106 = INDEFINITE	T24 = 0	T630 = 0
T640 = 50.0000000	T670 = 120.000000	T680 = 0	T690 = 0
WATER = INDEFINITE			

GRAPHICAL SIMULATION RESULTS 11/08/72 11.57.12.

GRAPH NO.	GROUP NO.	INDEPENDENT VARIABLE	DEPENDENT VARIABLE(S)	PLOTTED CHARACTER
1	1	TIME	X(24)	B
1	2	TIME	X(28)	C
1	3	TIME	T24	D
2	1	TIME	X(100)	E
2	2	TIME	X(101)	F
2	3	TIME	X(102)	G
2	4	TIME	F1029	H
3	1	TIME	X(106) X(110)	J K
3	2	TIME	X(121)	L
4	1	TIME	F1216 F1267	M N
4	2	TIME	X(126)	O
5	1	TIME	X(127)	P
5	2	TIME	X(199)	Q
5	3	TIME	F2710(1) F2710(2) F2710(3)	R S T
6	1	TIME	X(691) X(692) X(693)	U V W
6	2	TIME	T690	X
7	1	TIME	X(730)	Y
7	2	TIME	D73	Z

Fig. 29 through 36. Carbon, decomposer, and phosphorus output for lichens at a lichen heath.

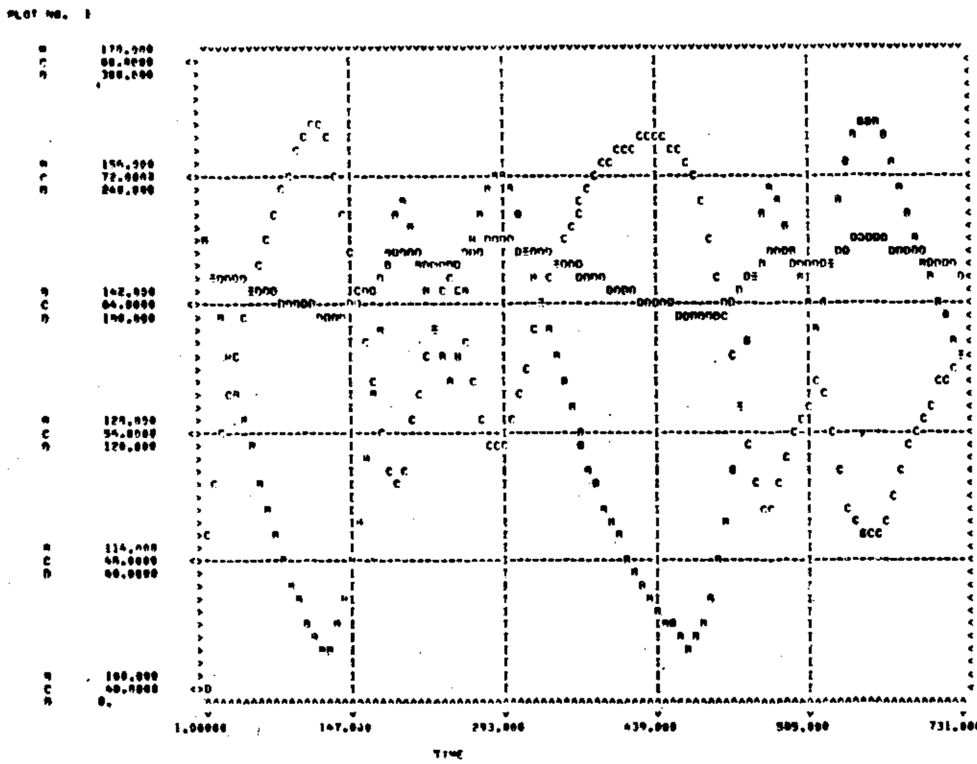

Fig. 30.

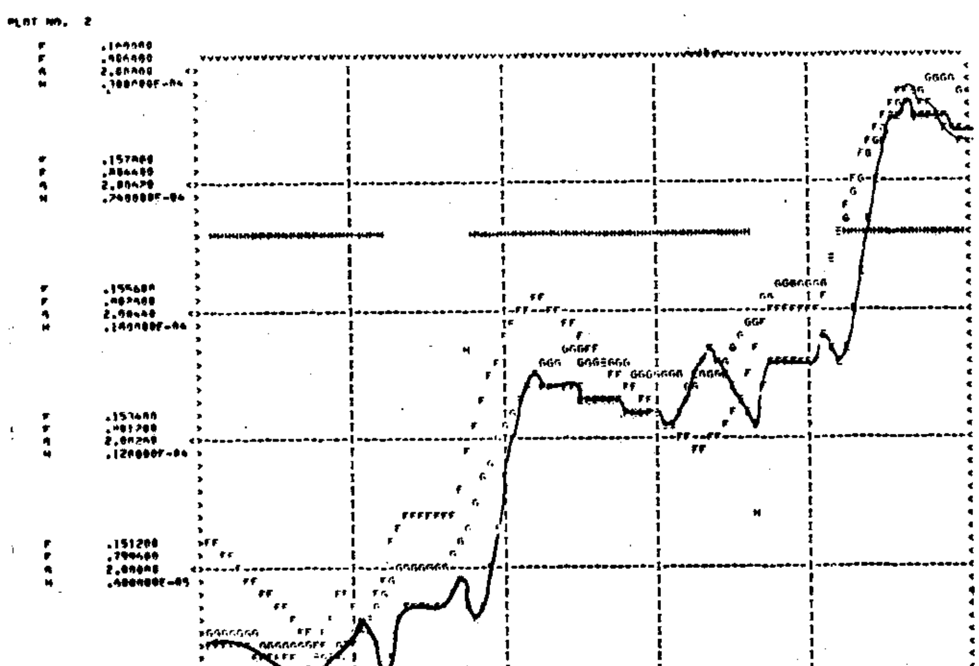

Fig. 31.

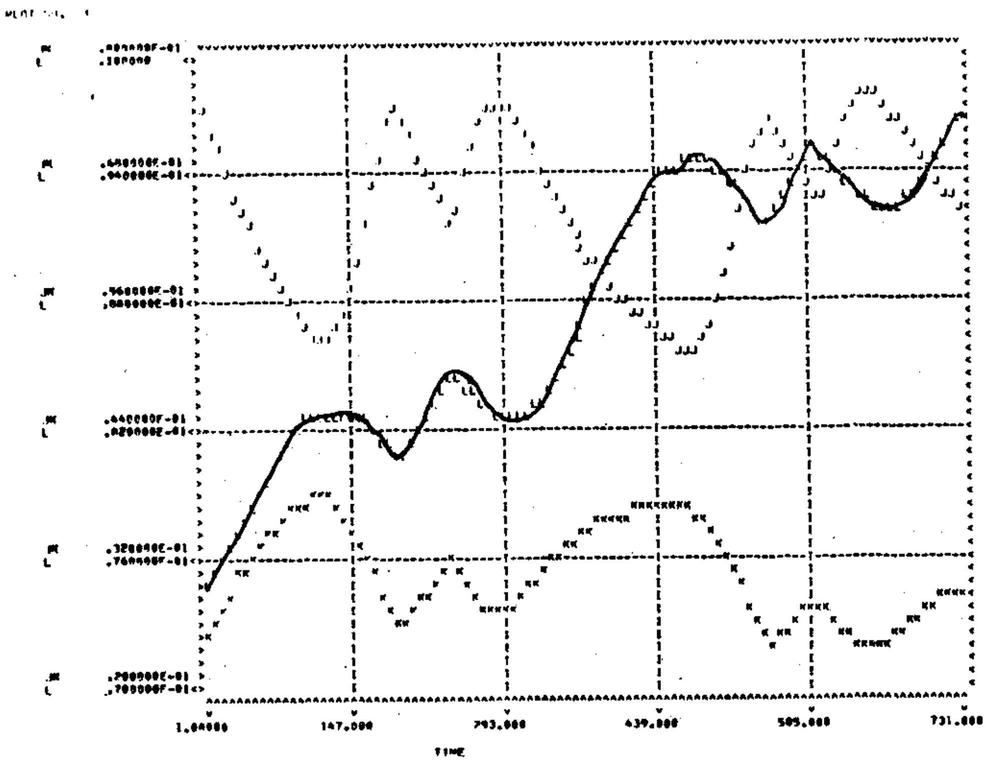
1.00000
147.000
293.000
439.000
585.000
731.000
TIME

Fig. 32.

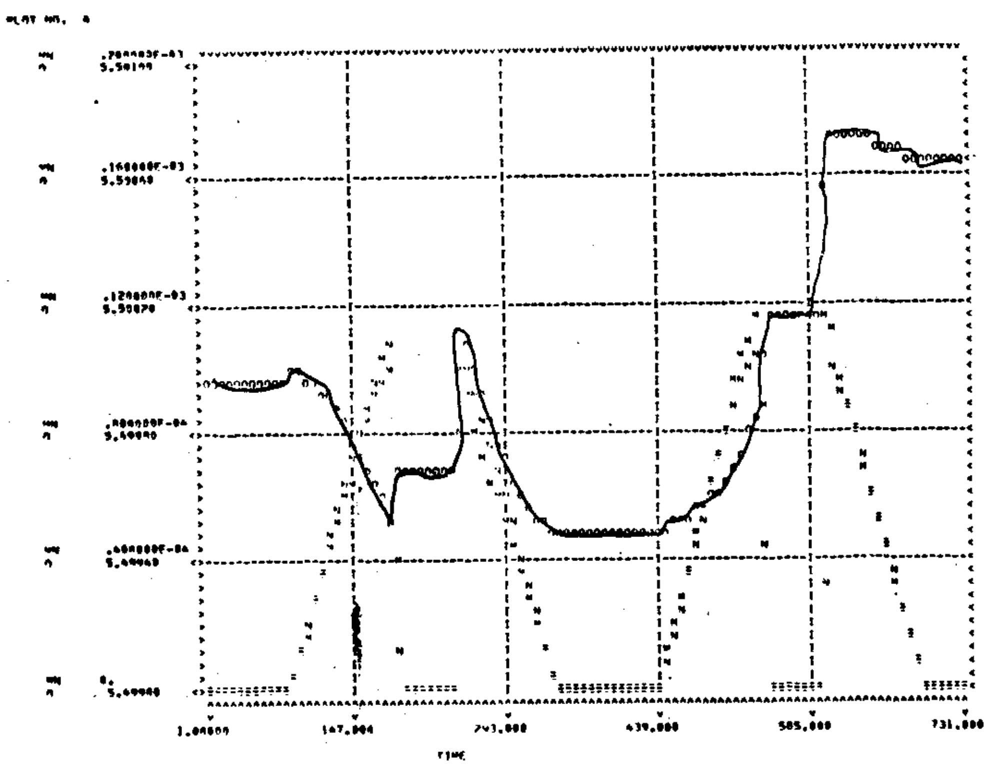
1.00000
147.000
293.000
439.000
585.000
731.000
TIME

Fig. 33.

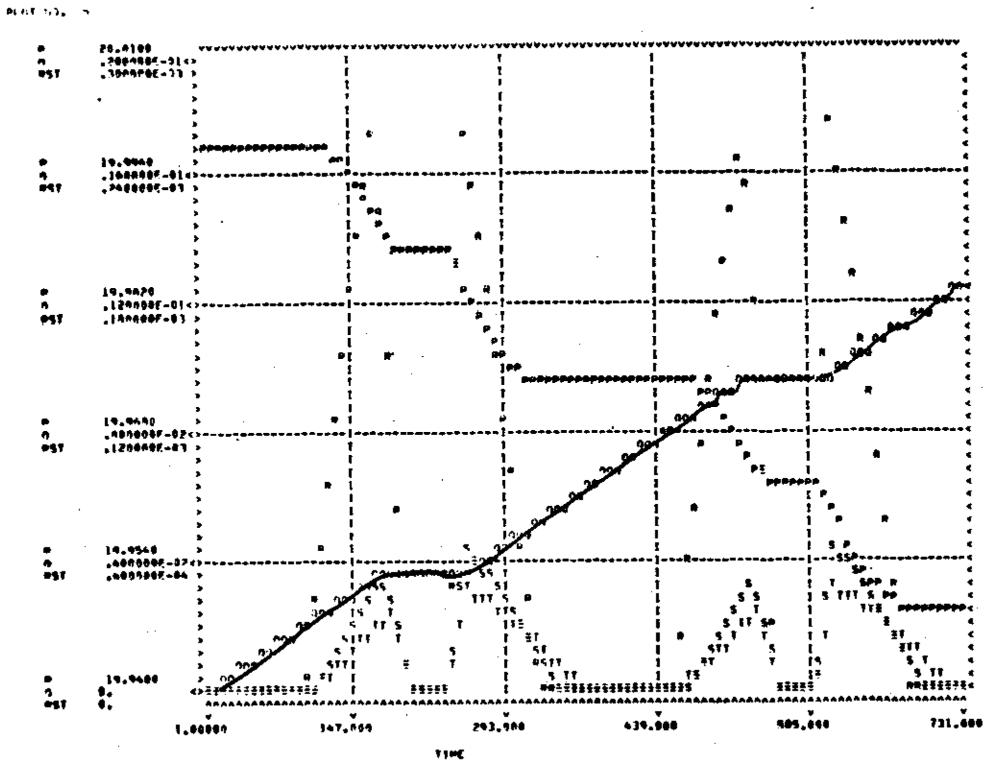
TIME
1.00000
147.000
293.000
439.000
585.000
731.000

Fig. 34.

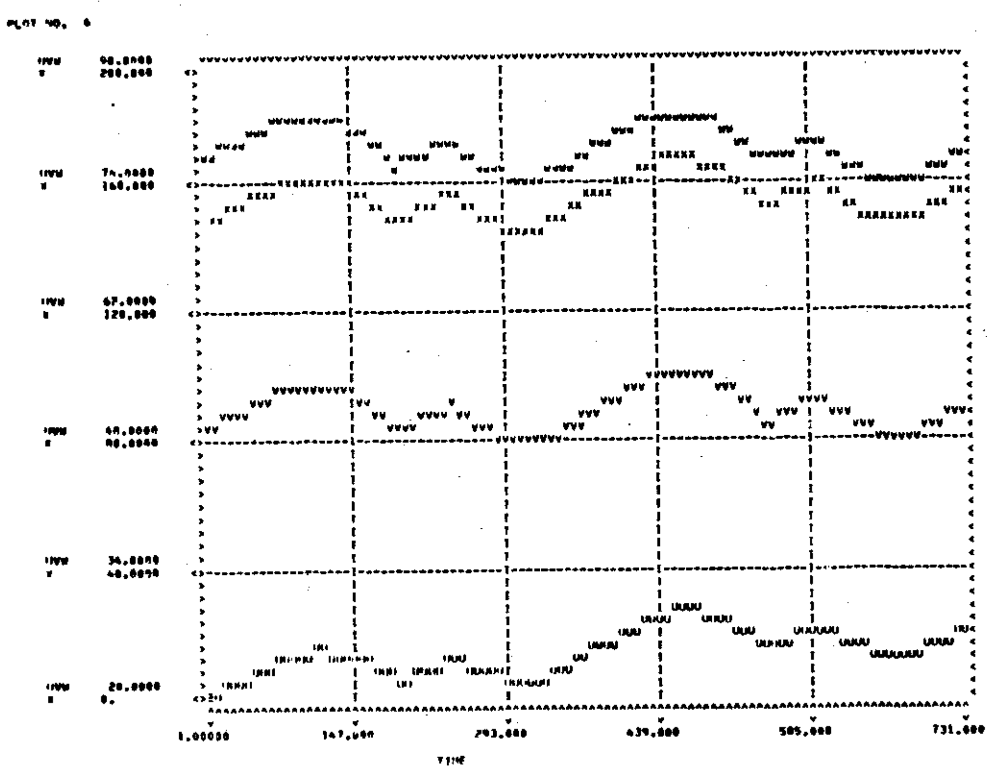
PLOT NO. 6
TIME
1.00000
147.000
293.000
439.000
585.000
731.000

Fig. 35.

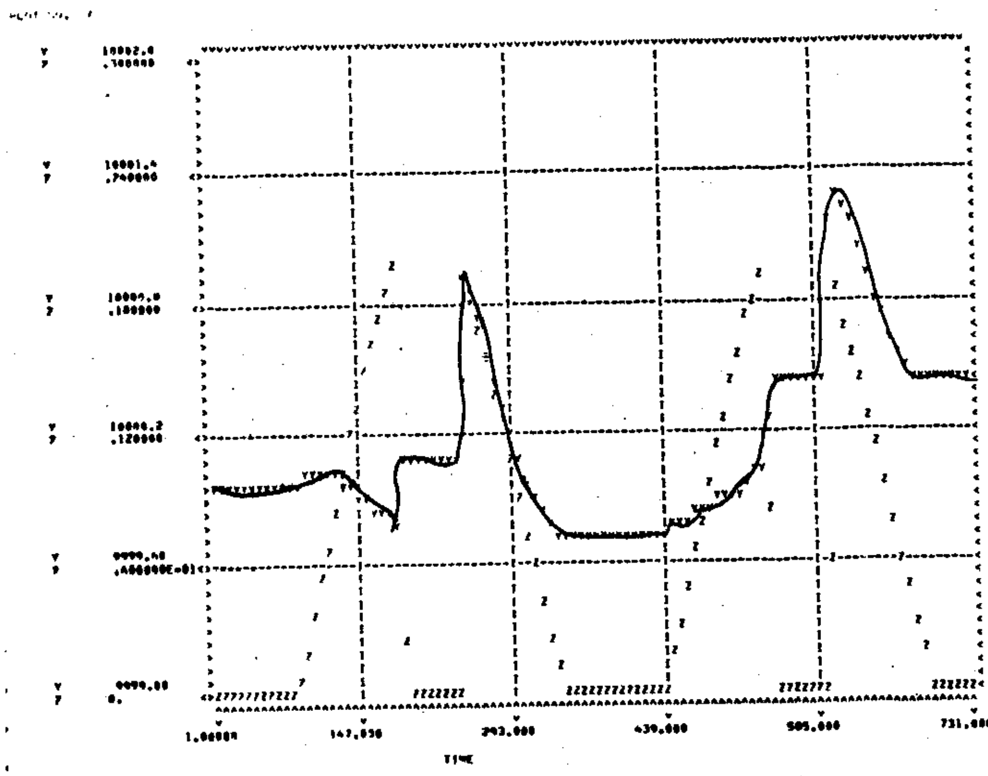

Fig. 36.

GRAPHICAL SIMULATION RESULTS 11/17/72 13.40.43.

GRAPH NO.	GROUP NO.	INDEPENDENT VARIABLE	DEPENDENT VARIABLE(S)	PLOTTED CHARACTER
1	1	TIME	X(22)	B
1	2	TIME	X(60)	C
1	3	TIME	X(26)	D
2	1	TIME	X(30)	E
2	2	TIME	X(34)	F
3	1	TIME	X(600)	G
3	2	TIME	X(730)	H
4	1	TIME	X(641) X(642) X(643)	J K L
5	1	TIME	X(671) X(672) X(673)	M N O

Fig. 37 through 42. Carbon and decomposer output for perennial herbaceous plants at a dry meadow.

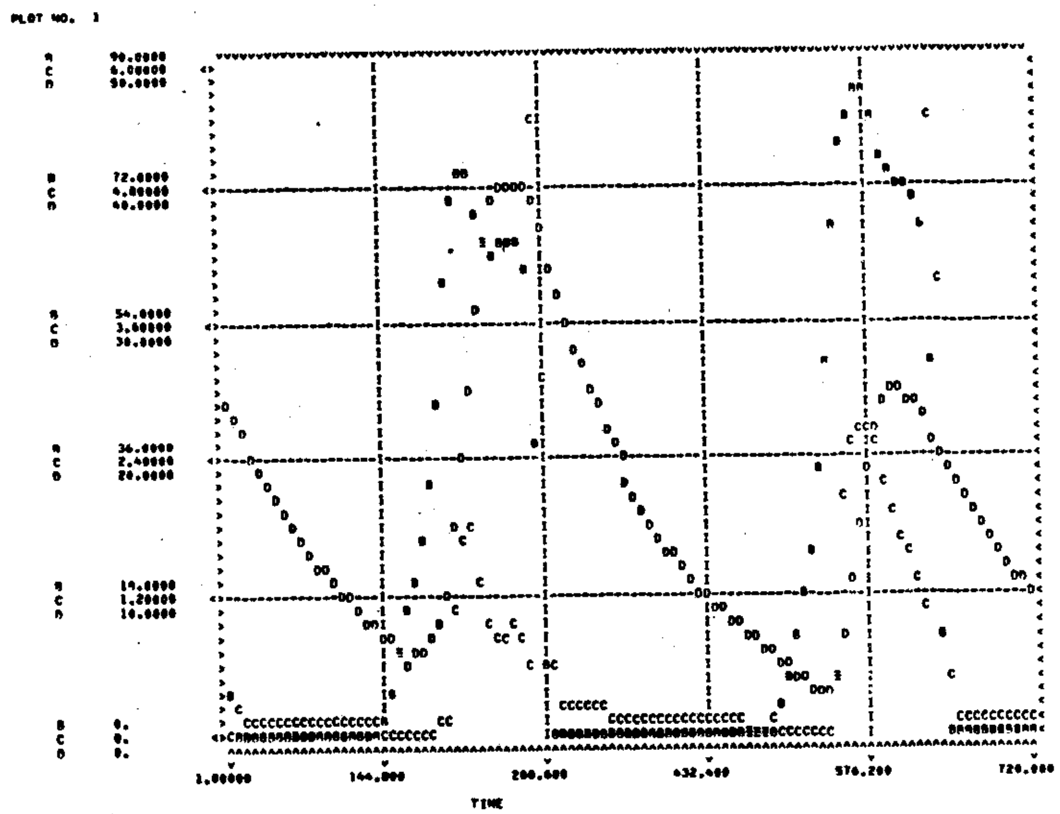
PLOT NO. 1
TIME
1.00000
144.000
288.600
432.400
576.200
720.000

Fig. 38.

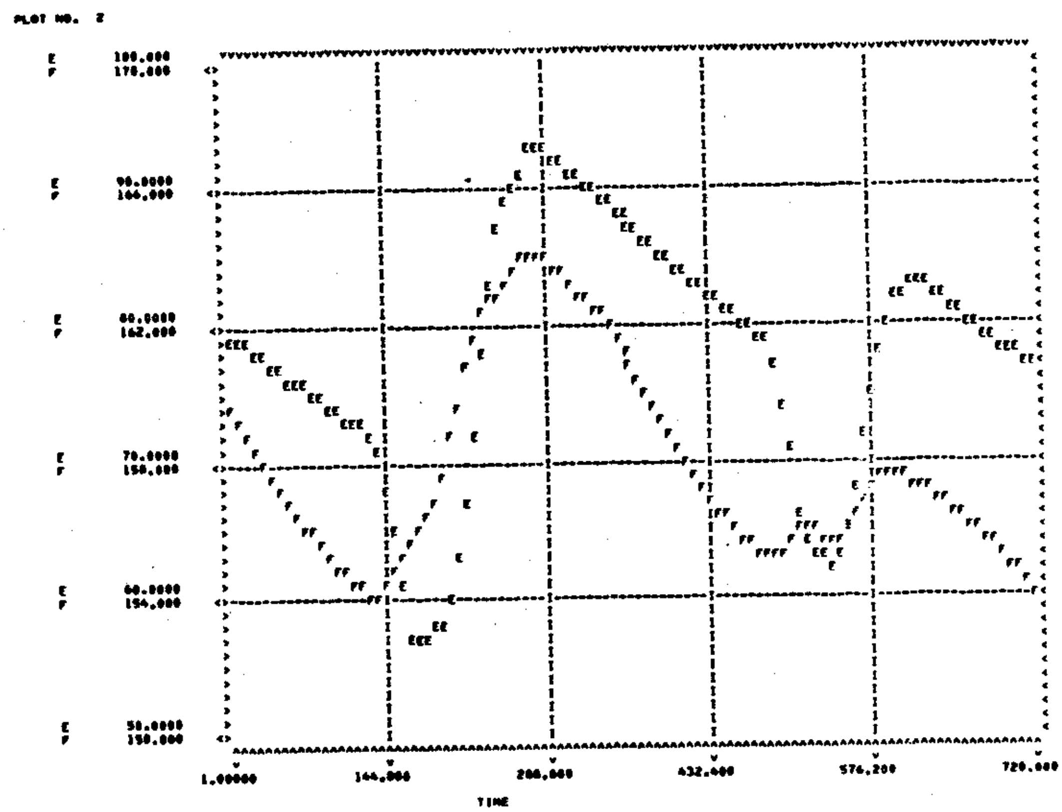
PLOT NO. 2
TIME
1.00000
144.000
288.000
432.400
576.200
720.000

Fig. 39.

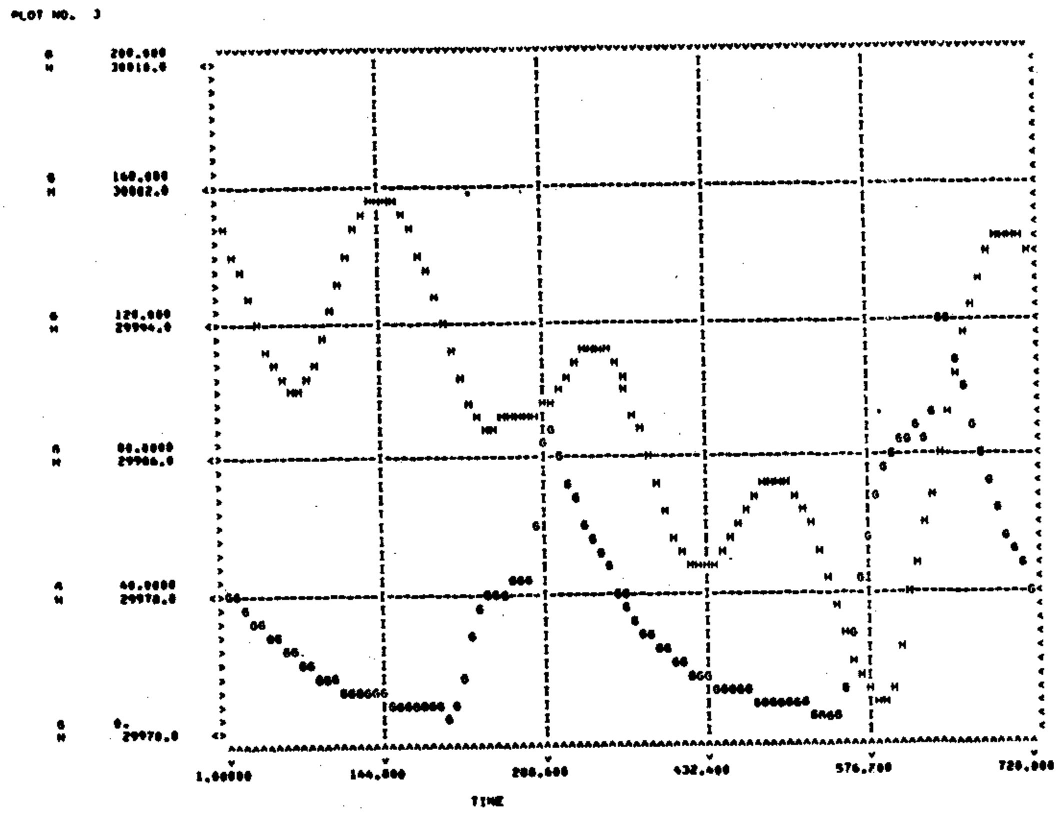

Fig. 40.

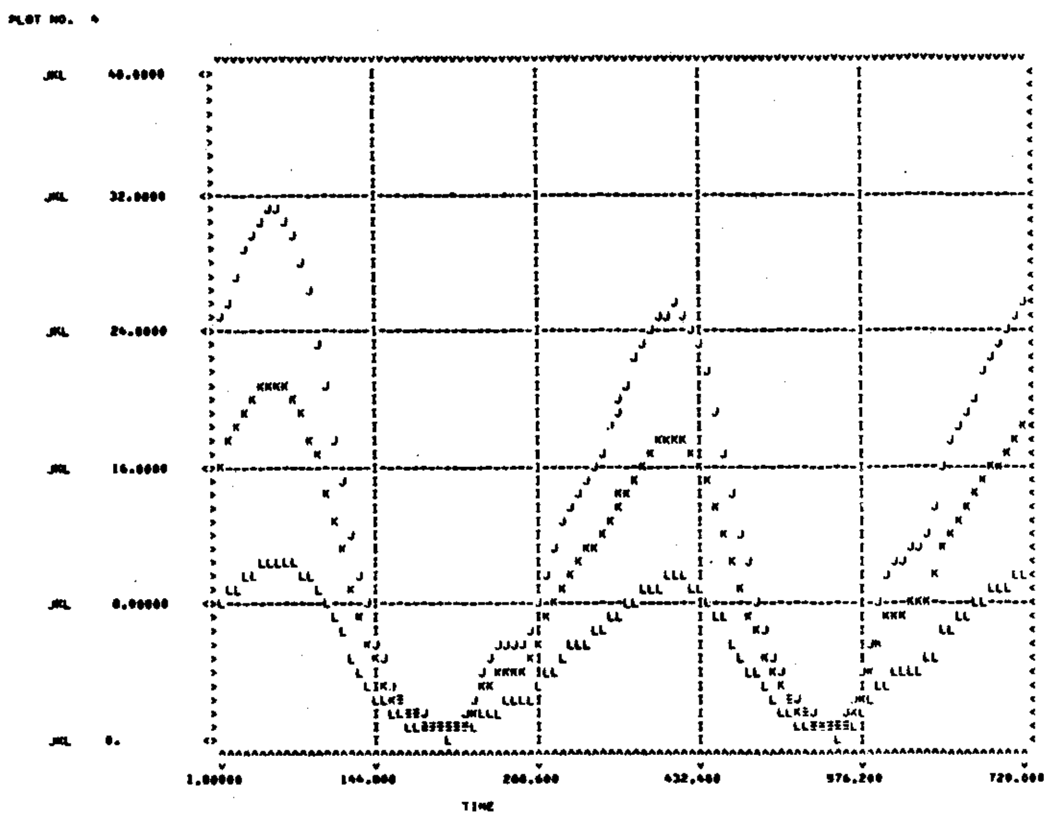

Fig. 41.

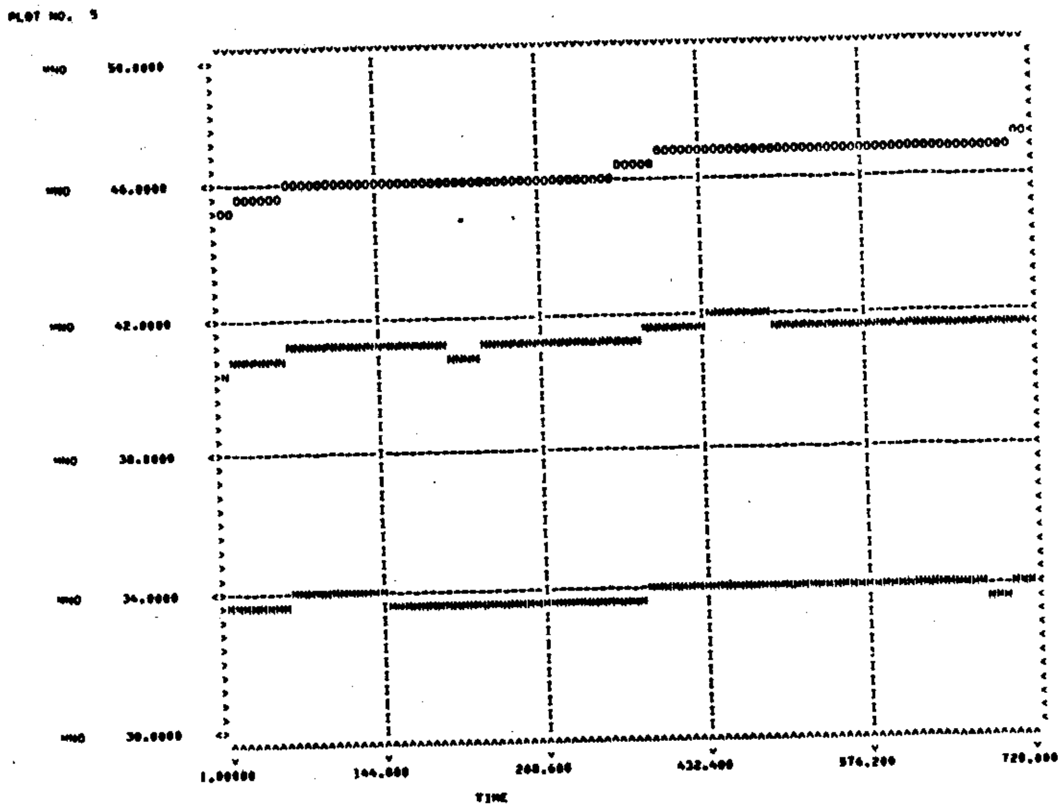

Fig. 42.

The relationship between plant biomass and productivity forms an interesting point of comparison between the two communities. It can be seen in Fig. 30 and 38 that biomass for lichens is of the order of twice that for perennial grasses. However, assimilation rates for lichens are much lower (by a factor of 0.1) both in terms of maximum assimilation rates (PMGR) and the actual modified rates following the assessment of the effect of plant and environmental factors. In addition, a great difference exists between the decomposition processes in the two communities, and this also contributes to the differences in biomass. Maximum decomposition rates (DMAXR) for grasses are taken to be almost twice those for lichens and, although it is felt that this sort of relationship must hold, there is doubt as to the actual magnitude of these processes. The maximum decomposition rates used here exceed the values considered reasonable on the basis of observation of decomposition using litter bag weight loss techniques. However, since the assimilation rates used are considered to be realistic, it is clear that higher rates are needed to explain why a considerable biomass and/or litter accumulation does not occur. As a means of synthesizing available data on these aspects of the Norwegian IBP effort, this modelling study has already proved itself to be of considerable value.

It is felt that the approach used here to construct simple functional relationships to describe flows between compartments has considerable value in the construction of low resolution models for intersite (international) comparisons. The model itself has some shortcomings and the absence of any real competitive relations between plant types has been stressed. In attending to omissions of this type, it would probably be necessary to restructure much of the model, but many of the ideas could be readily incorporated.

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The authors wish to thank the staff at the Natural Resource Ecology Laboratory, U.S. IBP Grassland Biome, and especially Dr. George Innis for advice in preparation of the model. Valuable programming help was given by Mr. Bob Robinson and Mr. Tim Simpson. The U.S. IBP Grassland Biome provided computer time. The publications staff at the NREL made it possible to get the paper finished within the time available. We wish to express our best thanks to all.

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APPENDIX I

APPENDIX TABLE

Appendix Table 1. Simulation control parameters for nitrogen and phosphorus; perennials at a dry meadow.

```
SIMCOMP VERSION 3.0          PARAMETER VALUES

                         - SIMULATION CONTROL PARAMETERS -

                              TIME  = INDEFINITE
                              TSTRT =  1.00000000
                              TEND  =  720.000000
                              DT    =  1.00000000
                              DTPR  =  30.0000000
                              DTPL  =           0
                              DTFL  =  30.0000000

                              - STATE VARIABLES -

                                                                                       X(100) =   2.80000000
       X(101) =   .600000000         X(102) =   .500000000         X(119) =            0         X(120) =   .468000000
   X(121-122) =            0         X(123) =   .575000000         X(124) =            0         X(125) =   1.38000000
       X(126) =   200.000000         X(127) =   300.000000     X(198-199) =   200.000000         X(200) =   1.08000000
   X(201-202) =   .150000000         X(219) =            0         X(220) =   1.30000000     X(221-222) =            0
       X(223) =   1.00000000         X(224) =            0         X(225) =   1.30000000         X(226) =   240.000000
       X(227) =   1500.00000     X(298-299) =   200.000000

                           - USER DEFINED VARIABLES -

FNEWY(1) =           0          FNFWY(2-3) =  1.00000000       FNEWY(4) =           0          FNMXN(1-4) =  .500000000E-01
FNN(1) =          0             FNN(2) =  2.80000000           FNN(3-5) =           0          FNN(6) =  1.70000000
FNN(7-9) =          0           FNN(10) =  1.70000000          FNN(11-13) =           0        FNN(14) =  1.30000000
FNN(15-16) =          0         FNPER(1-4) =  .400000000E-01   FNPNF(1) =           0          FNPNF(2) =  .200000000E-02
FNPNF(3-4) =          0         FNPRN =  .120000000E-01        FNST(1) =          0            FNST(2) =  20.0000000
FNTPR(1,1-4,1) =              0 FNTRR(1,2) =  2.50000000       FNTRR(2,2-3,2) =  1.50000000    FNTRP(4,2) =  1.00000000
FNTRR(1,3-4,4) =              0 FNWL(1) =           0          FNWL(2) =  .600000000           FNWL(3) =  .700000000
FNWT(1-2) =          0          FN200(1-4) =           0       FN211(1-6) =  1.00000000        FN220(1-6) =  1.00000000
FN221(1-2) =  1.00000000        FN227(1) =  .150000000E-04     FN227(2) =  .500000000F-05      FN227(3) =  .600000000E-07
FN227(4) = INDFFINITE           FPA(1-9) =           0         FPCP(1) =          0            FPCP(2) =  100.000000
FPEC(1) =  1.00000000           FPFC(2) =           0          FPFCX(1) =           0          FPECX(2) =  100.000000
FPECY(1) =          0           FPECY(2) =  1.00000000         FPEGX(1-2) =           0        FPEGY(1) =           0
FPEGY(2) =  1.00000000          FPEL(1) =           0          FPFL(2) =  1.00000000           FPEL(3) =           0
FPET(1) =          0            FPET(2) =  1.00000000          FPETX(1) =           0          FPETX(2) =  15.0000000
FPETY(1) =          0           FPETY(2) =  1.00000000         FPEW(1) =          0            FPEW(2) =  1.00000000
FPEWX(1-3) =          0         FPEWX(4) =  .600000000         FPFWY(1) =           0          FPFWY(2-3) =  1.00000000
FPEWY(4) =          0           FPH(1-3) =           0         FPMXP(1) =  .100000000F-04      FPMXP(2) =  .700000000E-03
FPMXP(3) =  .200000000F-03      FPMXP(4) =  .335000000E-04     FPP(1) =  1.00000000            FPP(2) =  .230000000
FPP(3-5) =          0           FPP(6) =  .115000000           FPP(7-9) =           0          FPP(10) =  .115000000
FPP(11-13) =          0         FPP(14) =  .115000000          FPP(15-16) =           0        FPPRP =  .400000000E-02
FPST(1) =          0            FPST(2) =  20.0000000          FPTRR(1,1) =  1.50000000        FPTRR(2,1-4,1) =  1.00000000
FPTRR(1,2) =  1.75000000        FPTRR(2,2) =  1.50000000       FPTRR(3,2) =  1.25000000        FPTRP(4,2) =  1.00000000
FPTRR(1,3-4,4) =              0 FPWL(1) =           0          FPWL(2) =  .600000000           FPWL(3) =  .700000000
FPWT(1-2) =          0          FP100(1-4) =           0       FP111(1-6) =  1.00000000        FP120(1-6) =  1.00000000
FP121(1-2) =  1.00000000        FP127(1) =  .300000000E-04     FP127(2) =  .350000000E-05      FP127(3) =  .800000000E-06
FX(1-4) = INDEFINITE            FY(1-4) = INDEFINITE           FZ(1-3) =           0           F1029 =           0
F1216 =          0              F1267 =           0            F2710(1-3) =           0

FNCN(1) =          0            FNCN(2) =  300.000000          FNFC(1) =  1.00000000           FNEC(2) =           0
FNECX(1) =          0           FNFCX(2) =  300.000000         FNFCY(1) =           0          FNECY(2) =  1.00000000
FNEGX(1-2) =          0         FNEGY(1) =           0         FNEGY(2) =  1.00000000          FNEL(1) =           0
FNEL(2) =  1.00000000           FNEL(3) =           0          FNET(1) =          0            FNET(2) =  1.00000000
FNETX(1) =          0           FNETX(2) =  15.0000000         FNETY(1) =           0          FNETY(2) =  1.00000000
FNEW(1) =          0            FNEW(2) =  1.00000000          FNEWX(1-3) =           0        FNEWX(4) =  .600000000
```