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P. W. Lommen

D. C. Wilkin

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1975/76 PROGRESS REPORT

PROGRAMMING PHASE OF WATER RESPONSE ECOSYSTEM MODEL: IV. PERENNIAL PLANT, NITROGEN AND DECOMPOSITION SUBMODELS

P. W. Lommen* and D. C. Wilkin**
Utah State University

(*now at HDR Ecosciences, Santa Barbara, California)
(**now at University of Illinois)

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Ecology Center, Utah State University, Logan, Utah 84322

This report describes a portion of the Desert Biome Water Response Ecosystem Model. Five Research Memoranda comprise the full description: Introduction and support programs (RM 76-36); Abiotic submodels (RM 76-37); Animal submodel (RM 76-38); Perennial plant, nitrogen and decomposition submodels (RM 76-39); and Annual plant submodel (RM 76-40). The objectives of the Water Response Model, information on the arrangement of material distributed among the five Research Memoranda and descriptions of program MAIN and support programs F1, F3 and FTAVE are contained in Research Memorandum 76-36, **Programming phase of water response ecosystem model: I. Introduction and support programs.** The relationships between various sections of the model, their interactions and location in the report series are summarized in Table 1 of RM 76-36.

A. PERENNIAL PLANT SUBMODEL (including VEG, VPHEN, VGROW, VTRANS VDETH and FWVP)

P. W. Lommen and D. C. Wilkin

GENERAL DESCRIPTION OF THE PERENNIAL VEGETATION SUBMODEL

Introduction

Each time-step, the perennial vegetation submodel determines new values for perennial plant biomass amounts. Thus, the values produced by this submodel, along with those produced by the annual vegetation submodel, are the values by which we expect to validate the entire Water Response Ecosystem Model. A statement of the model objective is included in Lommen (1976). As might be expected with a submodel of central importance, the interactions between this submodel and the remainder of the overall model are maximal: direct information from all other submodels, except for the annual plant submodel in which there is an indirect information flow with annual plants through soil water, is needed to determine perennial plant biomass amounts. The direct connections include: biomass removal by herbivory (animal subroutine; Heasley 1976); photosynthesis rates affected by soil water potential (Lommen and Marshall 1976, Section C); soil temperature (Lommen and Marshall 1976, Section B); soil mineral nitrogen levels (Sections B and C of this Research Memorandum); and environmental variables of relative humidity, air temperature, fraction of possible sunlight and photoperiod (Lommen and Marshall, Section A). A simplified box-and-arrow diagram is shown in Figure A-1.

The perennial vegetation is tracked time-step by time-step by separating it into functional groups (hereafter FG) and plant parts (hereafter PP). That is, perennial species which do, or will, constitute 85% of the perennial plant biomass of the site are divided into six or less FG's. Each FG consists of six PP's or organs: leaf, fruit, flower, new stem, old stem and root. The simulation is done on an area basis (the units used for biomass amounts are kg dry wt$\cdot$ha^{-1}).

The mechanisms incorporated in this submodel were decided upon after lengthy discussions with a large number of Desert Biome investigators, including S. Bamberg, A. Vollmer and T. Ackerman at the Rock Valley site in Nevada; A. Wallace and E. Romney at UCLA; J. Ludwig, G. Cunningham and J. Reynolds at Las Cruces; D. Patten at Tempe; and M. Caldwell, E. DePuit and R. Shinn at Utah State. Although there is no absolute agreement or concensus among these individuals on any part of the model, a general pattern of agreement has emerged which, in conjunction with the photosynthesis modeling work of Schultze et al. (1974), produces a model that appears to begin approximating the plant function for present purposes. It was conceived and designed as a general plant model whose specificity for any site depends on parameters furnished as input data.

The bulk of this submodel is contained in a FORTRAN program called VEG. There are four subsections of VEG, each of which does a specific task: 1) VPHEN, which determines phenophases (hereafter PHPH); 2) VTRANS, which calculates transpiration; 3) VGROW, which allocates photosynthate produced; 4) VDETH, which determines plant death.

Growth

Each calendar year the submodel causes every FG to go through all its PHPH's once. The usual sequence of PHPH's simulated is as follows: 1) winter dormancy; 2) leafing out; 3) vegetative growth; 4) reproductive growth; 5) postreproductive growth. These PHPH's can be parameterized, however, to simulate any desired sequence of growth patterns. All plants of a FG are assumed to be in one PHPH. The PHPH of a FG can change only once each time-step and no PHPH can be skipped.

A FG switches from one PHPH to the next whenever one or more of the following conditions occurs: 1) moisture degree-day sum, 10-day average temperature and environmental index are all above their respective thresholds (i.e., conditions are favorable enough to advance to the next PHPH); 2) 10-day average temperature is below a given limit (i.e., temperature is too cold to remain in present PHPH); 3) Julian date is greater than given limit (i.e., it is time to switch).

All limits and thresholds mentioned above depend on FG and current PHPH. Also, these parameters can be set so that a certain factor will never switch a particular FG from a given PHPH. For example, if a Julian date limit was set to a value greater than 365, then it would never cause a PHPH switch. Some ideas for PHPH switching came from grasslands work of French and Sauer (1974).

Once PHPH for a FG is determined, photosynthesis rate can be determined. The base rate depends on FG, plant part (PP) and PHPH. We allow for the possibility that all above-ground PP's may photosynthesize. This base rate is then multiplied by the number of daylight hours in the time-step, the biomass of the PP and an environmental factor. The environmental factor depends upon the following: 1) the soil water potential of the wettest soil layer, if that layer contains at least 10% of the FG's roots; 2) air temperature; 3) leaf temperature for optimum photosynthesis, which depends on average air temperature during the previous 15 days; 4) soil mineral nitrogen level; 5) water vapor density difference between leaf and air; 6) fraction of possible sunlight. Except for number 6, all of these items are parameterized for each FG.

When the photosynthesis amounts for the various above-ground PP's are summed, we get the net photosynthesis for the FG for the time-step of the above-ground PP's during daylight hours.

Respiration must be determined for above-ground PP's during darkness, and for roots during all hours. The calculation made is very similar to the way net photosynthesis is calculated. The calculation of the environmental factor, however, is simpler. It depends on soil water potential and air temperature for above-ground PP's and on soil water potential and soil temperature for roots.

The difference between photosynthesis and respiration for a FG is the net primary production or the net photosynthate which needs to be allocated to the various PP's. Allocation is simulated as a two-phase process. In the first phase, the proportion of each PP in its FG's total biomass is brought up toward its nominal proportion. The nominal proportion depends on environmental conditions, PHPH, PP and FG. The rate of increase of a PP depends on a "half-time," which is PHPH-, PP- and FG-dependent. Thus, flowers can be brought up to nominal proportions quickly, but new stems can be required to take longer. If, somehow, a PP is at, or above, nominal proportions, no photosynthate is allocated to it (or removed from it). First-phase allocation amounts are not directly related to amount of photosynthate available. There is an indirect relation between these amounts via environmental conditions.

The second phase of the allocation allocates the remainder of the photosynthate. This remainder could be negative, in which case allocation is essentially a translocation to PP's favored in the first phase of the allocation from other PP's (roots, chiefly).

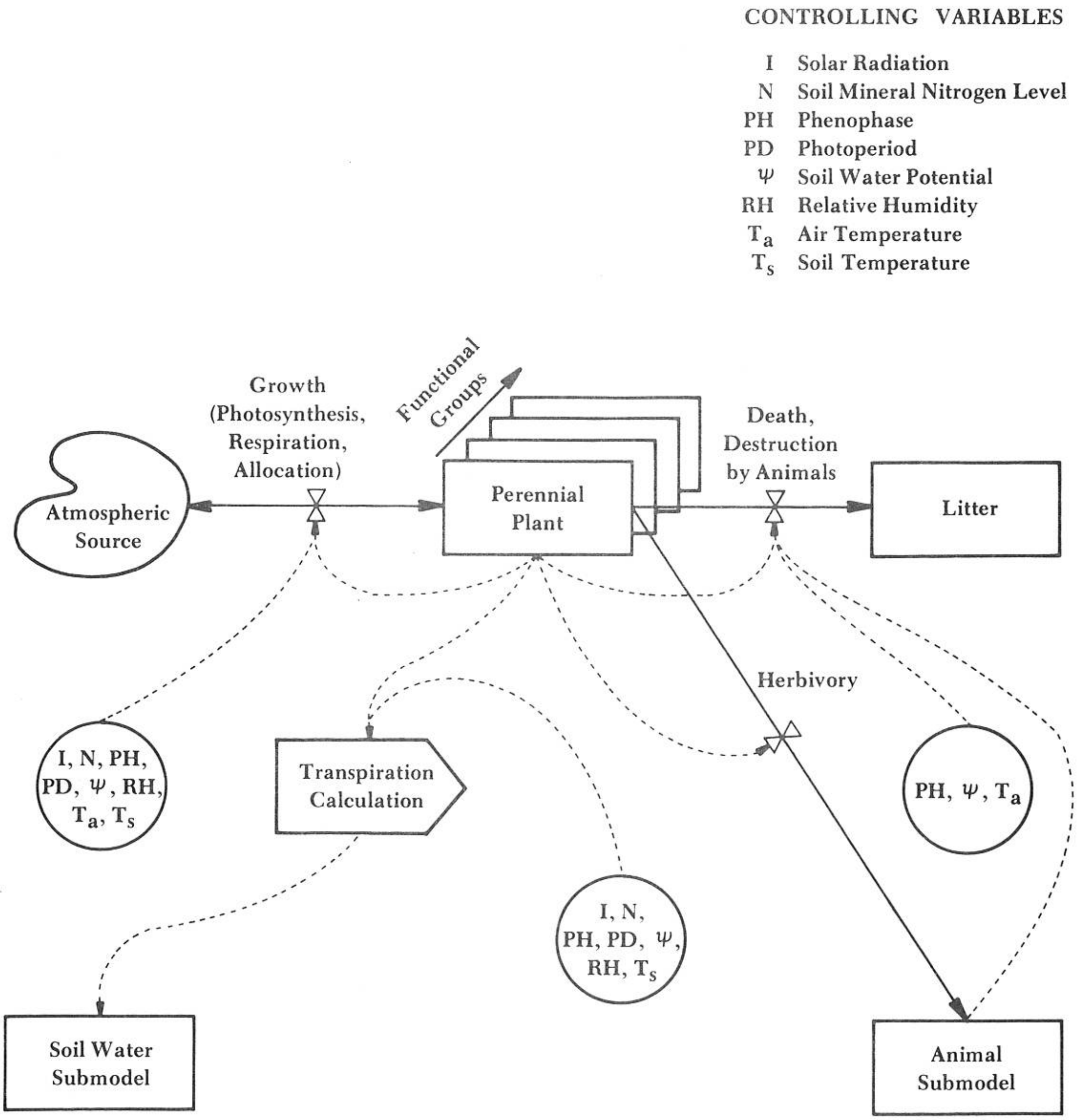

Figure A-1. Simplified box-and-arrow diagram for the perennial plant submodel. Herbivory and destruction by animals are calculated in the animal submodel (Heasley 1976; RM 76-38).

The first step in phase two of allocation is to give roots a portion of the remainder determined by a root:shoot allocation ratio which depends on environmental conditions, PHPH and FG. The shoots (or above-ground PP's) get the rest. Each shoot PP gets an amount proportional to its biomass and a proportionality factor dependent on environmental conditions and PHPH. If the shoots' share is negative, another proportionality factor multiplies leaf and reproductive parts, so that less is taken from them.

Death

Nominal, instantaneous death rates are calculated for each PP and depend on environmental conditions, PHPH, PP and FG. The root death rate is adjusted by multiplying by the ratio of the actual root:shoot ratio to the nominal root:shoot ratio (which depends on environmental conditions, PHPH and FG). This adjustment will tend to move the two ratios together. The amount of a PP dying in the time-step then, is given by the following formula:

$$\text{(amount dying)} = \text{(amount alive)} \{ 1 - \exp [-\text{(death rate)} \text{(length of time-step)}] \} \quad \text{(A-1)}$$

These amounts are then removed from live biomass categories. Equal amounts are added to appropriate litter categories.

Transpiration

A value of transpiration for each FG is calculated in the perennial plant submodel and passed to the soil water submodel which removes the water from the soil profile.

First, P:T, the ratio of photosynthesis to transpiration, is calculated as a linear function of water vapor pressure between leaf and air. If leaf temperature is not optimum, P:T is multiplied by a factor which depends on the difference between actual and optimum leaf temperature. Typically, the maximum value of this factor is about 2, when optimum is 10 C above air temperature. Once P:T for each FG is calculated, actual transpiration values are determined from P:T and values for photosynthesis calculated earlier.

Cover

Finally, a value for soil surface covered by perennial vegetation is calculated by a simple method. We assume cover is proportional to the 2/3 power of the total perennial vegetation biomass on the site.

PROGRAM DESCRIPTION

Subroutine VEG

Only the important segments of the FORTRAN code are shown and described. Sequence numbers are shown to aid in reference to the full code listing which follows. Comment cards, specification statements and bookkeeping sections have been deleted. Definitions of variable names may be found in Table A-1, which also appears at the beginning of the Program Listing.

Table A-1. Variable dictionary for VEG

```
CAAR(J,K)     AMOUNT OF PLANT PART K, FUNCTIONAL GROUP J, INGESTED
              BY ANIMALS DURING THE TIME STEP, KG HA-1.

CADEST(J,K)   AMOUNT OF LIVE PLANT PART K, FUNCTIONAL GROUP J,
              TRANSFERRED BY ANIMAL ACTIVITY FROM PLANT TO SURFACE
              LITTER DURING TIME STEP, KG HA-1.

CUMPSN(J)     ACCUMULATED PHOTOSYNTHATE PRODUCTION FROM JANUARY 1
              FOR FUNCTIONAL GROUP J, KG HA-1.

CUMRSP(J)     ACCUMULATED RESPIRATORY LOSSES FROM JANUARY 1 FOR
              FUNCTIONAL GROUP J, KG HA-1.

CUMTRP(J)     ACCUMULATED TRANSPIRATION FOR FUNCTIONAL GROUP J
              FROM JANUARY 1, KG HA-1.

CVPHS(J)      NET PHOTOSYNTHATE PRODUCTION OF FUNCTIONAL GROUP J
              DURING THE DAYLIGHT PART OF THE TIMESTEP, KG HA-1.

CVRDST(J,K)   FRACTION OF TOTAL ROOT BIOMASS OF FUNCTIONAL GROUP J
              FOUND IN SOIL LAYER K, 0 TO 1.

CVTSPR(J,K)   WATER TRANSPIRED FROM SOIL LAYER K BY FUNCTIONAL
              GROUP J DURING THE TIME STEP, KGWATER HA-1.

CVVCOV        FRACTION OF SOIL SURFACE COVERED BY VEGETATION, 0 TO 1.

CWPSI(K)      SOIL WATER POTENTIAL IN SOIL LAYER K, BAR.

D             TEMPORARY VARIABLE USED IN ANIMAL REMOVAL SECTION.

DATA1(L,2,J)  DATA PAIRS (L IN NUMBER) RELATING AVERAGE
              AIR TEMPERATURE TO OPTIMUM PHOTOSYNTHESIS AIR
              TEMPERATURE (BOTH DEGREES CELSIUS) FOR
              FUNCTIONAL GROUP J.
```

Table A-1, continued

DATA3(L,2,J)	DATA PAIRS (L IN NUMBER) FOR FUNCTIONAL GROUP J, RELATING SOIL MINERAL NITROGEN CONCENTRATIONS IN KG HA-1 TO A PHOTOSYNTHESIS SCALING FACTOR, 0 TO 1.
DATA9(L,2)	DATA PAIRS (L IN NUMBER) RELATING THE FRACTION OF POSSIBLE SUNLIGHT HOURS DURING THE PHOTOPERIOD TO A SCALING FACTOR FOR PHOTOSYNTHESIS, 0 TO 1.
DATA51(NR51,NC51,J)	ARRAY CONTAINING A 2-DIMENSIONAL MATRIX FOR EACH FUNCTIONAL GROUP J FOR USE WITH FUNCTION F3. EACH 2-DIMENSIONAL MATRIX HAS NR51 ROWS AND NC51 COLUMNS AND IS A FAMILY OF RELATIVE NET PHOTOSYNTHESIS VS. TEMPERATURE CURVES FOR VARIOUS VALUES OF SOIL WATER POTENTIAL.
DATA52(NR52,NC52,J)	ARRAY CONTAINING A 2-DIMENSIONAL MATRIX FOR EACH FUNCTIONAL GROUP J FOR USE WITH FUNCTION F3. EACH 2-DIMENSIONAL MATRIX HAS NR52 ROWS AND NC52 COLUMNS AND IS A FAMILY OF RELATIVE NET PHOTOSYNTHESIS VS. SOIL WATER POTENTIAL CURVES FOR DIFFERENT VALUES OF WATER VAPOR DENSITY DIFFERENCE BETWEEN LEAF AND AIR.
DATA53(NR53,NC53,J)	ARRAY CONTAINING A 2-DIMENSIONAL MATRIX FOR EACH FUNCTIONAL GROUP J FOR USE WITH FUNCTION F3. EACH 2-DIMENSIONAL MATRIX HAS NR53 ROWS AND NC53 COLUMNS AND IS A FAMILY OF RELATIVE DARK RESPIRATION VS. TEMPERATURE CURVES FOR VARIOUS VALUES OF SOIL WATER POTENTIAL.
DBGFLG	LOGICAL DEBUGGING FLAG. IF EQUALS .TRUE. DEBUGGING INFORMATION IS WRITTEN THIS TIME STEP.
DEBUG3	PRESET TO A VALUE 'N', PRINTS DEBUGGING INFORMATION EVERY N-TH TIME STEP BEGINNING WITH TIME STEP NUMBER ONE.
DT	EQUALS PMOT. LENGTH OF TIMESTEP, DAY.
F1	A ONE DIMENSIONAL INTERPOLATION FUNCTION.
F3	TWO DIMENSIONAL INTERPOLATION FUNCTION.
FTAVE(PMOT,N)	FUNCTION TO AVERAGE PREVIOUS N DAYS' AIR TEMPERATURES BY AVERAGING APPROPRIATE NUMBER OF PREVIOUS TIME STEP AVERAGE TEMPERATURES.
FWVP(T)	FUNCTION WHICH, GIVEN T IN DEGREES CELSIUS, CALCULATES SATURATION WATER VAPOR PRESSURE IN MB.
I	INDEX VARIABLE.
J	USED AS PLANT FUNCTIONAL GROUP SUBSCRIPT.
K	USED VARIOUSLY AS PLANT PART SUBSCRIPT, OR SOIL LAYER SUBSCRIPT.
L	INDEX VARIABLE.
M	INDEX VARIABLE USED TO INDICATE LITTER LOCATION.
N	USED AS SUBSCRIPT OF WETTEST SOIL LAYER.
NC51	NUMBER OF COLUMNS IN EACH OF THE PMFGPS 2-DIMENSIONAL MATRICES MAKING UP THE DATA51 ARRAY.
NC52	NUMBER OF COLUMNS IN EACH OF THE PMFGPS 2-DIMENSIONAL MATRICES MAKING UP THE DATA52 ARRAY.
NC53	NUMBER OF COLUMNS IN EACH OF THE PMFGPS 2-DIMENSIONAL MATRICES MAKING UP THE DATA53 ARRAY.
NNN	PHENOPHASE OF CURRENT PLANT GROUP.
NPTS1(J)	NUMBER OF DATA PAIRS IN DATA1, FUNCTIONAL GROUP J.
NPTS3(J)	NUMBER OF DATA PAIRS IN DATA3 FOR FUNCTIONAL GROUP J.
NPTS9(1)	NUMBER OF DATA PAIRS IN DATA9.
NR51	NUMBER OF ROWS IN EACH OF THE PMFGPS 2-DIMENSIONAL MATRICES MAKING UP THE DATA51 ARRAY.
NR52	NUMBER OF ROWS IN EACH OF THE PMFGPS 2-DIMENSIONAL MATRICES MAKING UP THE DATA52 ARRAY.
NR53	NUMBER OF ROWS IN EACH OF THE PMFGPS 2-DIMENSIONAL MATRICES MAKING UP THE DATA53 ARRAY.

Table A-1, continued

PMDT	LENGTH OF TIMESTEP, DAY.
PMFGPS	NUMBER OF PLANT FUNCTIONAL GROUPS BEING SIMULATED.
PMJDAT	JULIAN DATE OF THE CURRENT TIME STEP.
PMJDAY	JULIAN DATE OF THE CURRENT TIME STEP. EQUALS PMJDAT.
PMLYRS	NUMBER OF SOIL LAYERS BEING SIMULATED.
PVCOV	PARAMETER USED IN COVER CALCULATION
PVPRAT(J,K)	MAXIMUM POSSIBLE PHOTOSYNTHESIS RATE OF PLANT PART K, FUNCTIONAL GROUP J, KG KG-1 HR-1.
PVRRAT(J,K)	MAXIMUM RESPIRATORY RATE OF PLANT PART K, FUNCTIONAL GROUP J, KG KG-1 HR-1.
Q	TEMPORARY VARIABLE USED TO DETERMINE VALUE OF DBGFLG.
RCHECK	ARRAY USED TO READ AND WRITE COMMENTS IN INPUT DATA.
T	TEMPORARILY USED TO HOLD VALUE OF RESPIRATION OF PHOTOSYNTHESIZING PARTS DURING DARK HOURS, KG HA-1.
TRRFAC	SCALING FACTOR FOR RESPIRATION OF PHOTOSYNTHESIZING PARTS, DECIMAL FRACTION, 0 TO 1.
TVPFAC(2)	AFTER INTERMEDIATE USE, BECOMES A SCALING FACTOR FOR PHOTOSYNTHESIS RATE DEPENDING ON AIR TEMPERATURE (IN DEGREES CELSIUS) AND SOIL WATER POTENTIAL (IN BARS), -.3 TO 1.
TVPFAC(3)	PHOTOSYNTHESIS SCALING FACTOR DEPENDING ON SOIL MINERAL NITROGEN CONCENTRATION (IN KG HA-1), 0 TO 1.
TVPFAC(5)	AFTER INTERMEDIATE USE, BECOME A SCALING FACTOR FOR PHOTOSYNTHESIS RATE DEPENDING ON RELATIVE HUMIDITY, 0 TO 1.
TVPFAC(7)	A SCALING FACTOR FOR PHOTOSYNTHESIS RATE DEPENDING ON FRACTION OF POSSIBLE SUNLIGHT HOURS, 0 TO 1.
TVPP(J)	PHENOPHASE OF PLANT GROUP J.
TVPSI	SOIL WATER POTENTIAL IN THE WETTEST LAYER CONTAINING AT LEAST 10 PER CENT OF THE ROOTS OF THE PLANT FUNCTIONAL GROUP, BAR.
TVPS2	SOIL WATER POTENTIAL OF THE ROOT ZONE WEIGHTED BY ROOT DISTRIBUTION, BAR.
TVRFAC	A SCALING FACTOR FOR RESPIRATION RATE FOR ROOTS AS A FUNCTION OF SOIL TEMPERATURE (IN DEGREES CELSIUS) AND SOIL WATER POTENTIAL (IN BAR), 0 TO 1..
TVRSPR	DARK RESPIRATION. EQUALS SUM OF RESPIRATION OF PHOTOSYNTHESIZING PARTS DURING DARKNESS AND RESPIRATION OF ROOTS FOR ALL HOURS DURING THE TIMESTEP, KG HA-1.
TVSOLT	TIME STEP AVERAGE WEIGHTED MEAN SOIL TEMPERATURE WEIGHTED BY ROOT DISTRIBUTION OF THE FUNCTIONAL GROUP, DEGREES CELSIUS.
TVTCOR	CORRECTION TERM FOR TEMPERATURE ACCLIMATION, DEG. CELSIUS
VDETH	DEATH SUBROUTINE. SEE WRITE-UP ON VDETH FOR DETAILS.
VGROW	GROWTH SUBROUTINE. SEE WRITE-UP ON VGROW FOR DETAILS.
VPHEN	PHENOLOGY SUBROUTINE. SEE WRITE-UP ON VPHEN FOR DETAILS.
VTRANS	SUBROUTINE WHICH CALCULATES TRANSPIRATION. SEE WRITE-UP ON VTRANS FOR DETAILS.
X	INTERMEDIATE VARIABLE- VARIOUSLY USED.
XHSOLT(K)	TIME STEP AVERAGE SOIL TEMPERATURE IN SOIL LAYER K=1, DEGREES CELSIUS.
XNMN	SOIL INORGANIC (MINERAL) NITROGEN CONCENTRATION, KG HA-1
XVFG(J,K)	ABOVE GROUND BIOMASS OF PARTS OF FUNCTIONAL GROUP J. IF K=1, IT IS LEAVES, IF K=2, IT IS ALL REPRODUCTIVE STRUCTURE, IF K=3, IT IS NEW STEM, IFK=4, IT IS OLD STEM, AND IF K=5, IT IS TOTAL OF ALL ABOVE GROUND PLANT PARTS, KG HA-1.

Table A-1, continued

XVLITR(J,K)	MASS OF LITTER OF TYPE K, IN LOCATION J. LITTER TYPES ARE (1) FECES, (2) SOFT, (3) HARD, AND (4) WOOD. LITTER LOCATIONS ARE (1) STANDING DEAD, (2) GROUND SURFACE, AND (3 TO N) THE DEFINED SOIL LAYERS, KG HA-1.
XVPLNT(J,K)	BIOMASS OF PLANT PART K IN PLANT FUNCTIONAL GROUP J. THE PLANT PARTS SIMULATED ARE (1) LEAF, (2) FLOWER, (3) FRUIT, (4) NEW STEM, (5) OLD STEM, AND (6) ROOTS, KG HA-1.
XVTOTL	TOTAL ABOVE GROUND PLANT BIOMASS, KG HA-1.
ZAIRR	VARIABLE USED TO HANG ON TO TEMPERATURE TO WHICH NET PHOTOSYNTHESIS IS KEYED, DEGREES CELSIUS.
ZAIRT	AVERAGE DAILY MEAN AIR TEMPERATURE DURING TIME STEP, DEGREES CELSIUS.
ZPHPD	AVERAGE DAILY PHOTOPERIOD DURING THE TIME STEP, HR DAY-1.
ZSUN	AVERAGE ACTUAL FRACTION OF POSSIBLE SUNLIGHT HOURS FOR TIME STEP, 0 TO 1.
ZRH	AVERAGE 11 A.M. RELATIVE HUMIDITY DURING TIME STEP 0 TO 1
ZTMAX	AVERAGE DAILY MAXIMUM AIR TEMPERATURE DURING TIME STEP, DEGREES CELSIUS .
ZTMIN	AVERAGE DAILY MINIMUM AIR TEMPERATURE DURING TIME STEP, DEGREES CELSIUS.
ZZ	MAXIMUM OF TVPFAC(2) AND ZERO. USED AS AN ENVIRONMENTAL INDEX, DECIMAL FRACTION, 0 TO 1.

```
      DBGFLG=.FALSE.                                                    VEG 274
      IF (DEBUG3 .GT. 1E-5) Q=MOD(((TIME-TSTART)/DT),DEBUG3)            VEG 275
      IF((DEBUG3 .GT. 1.E-5) .AND. (Q .LT. 1.E-5)) DBGFLG=.TRUE.        VEG 276
      IF(DBGFLG) WRITE(3,10) PMJDAT                                     VEG 277
   10 FORMAT('0*****************     PMJDAT =', I4)                     VEG 278
```

Determine state of debugging flag. If DEBUG3 = N, then every N time-steps Q = 0 and debugging information is written.

```
      DO 200 J=1,PMFGPS                                                 VEG 300
```

Begin loop over FG, the main loop in the program.

```
      TVPSI=-3500.                                                      VEG 306
      N=0                                                               VEG 307
      DO 70 K=1,PMLYRS                                                  VEG 308
      IF (CVRDST(J,K)-.1) 70,40,40                                      VEG 309
   40 IF ((XMSOLT(K+1) .LE. 0.) .AND. ((CWPSI(K)-50.) .GT. TVPSI))      VEG 310
     1 GO TO 50                                                         VEG 311
      IF ((XMSOLT(K+1) .GT. 0.) .AND. (CWPSI(K) .GT. TVPSI)) GO TO 60   VEG 312
      GO TO 70                                                          VEG 313
   50 N=K                                                               VEG 314
      TVPSI=CWPSI(K)-50.                                                VEG 315
      GO TO 70                                                          VEG 316
   60 N=K                                                               VEG 317
      TVPSI=CWPSI(K)                                                    VEG 318
   70 CONTINUE                                                          VEG 319
```

Check all soil layers for the wettest layer having ⩾ 10% of FG's roots. If temperature of this layer ⩽ 0 C, add —50 bars to its water potential.

```
TVPFAC(2)=F1(FTAVE(PHDT, 15), DATA1(1,1,J), NPTS1(J))          VEG 324
TVTCOR=20.-TVPFAC(2)                                            VEG 325
X=ZAIRT+.35*(ZTMAX-ZAIRT)                                       VEG 326
TVPFAC(2) = F3 (X+TVTCOR, TVPSI, DATA51(1,1,J), NR51, NC51)     VEG 327
```

Calculate the photosynthesis factor for soil water potential (hereafter SWP) and air temperature. First, using interpolation function F1, optimum temperature is determined based on average temperature during the previous 15 days. TVTCOR is the difference between 20 C and the optimum just determined. The temperature 20 C is used because all the curves in DATA51 (line 327) are arbitrarily set equal to 1 (maximum value) at 20 C. X here is the temperature to which photosynthesis is keyed this time-step, and is slightly above average air temperature. Finally, using a temperature of X + TVTCOR and SWP equal to TVPSI, the value of this correction factor is interpolated from the family of curves for FG J found in array DATA51.

```
ZAIRR=X                                                         VEG 329
```

Since X is used again for other purposes, ZAIRR hangs on to its present value.

```
ZZ = AMAX1(TVPFAC(2), 0.0)                                      VEG 334
```

ZZ will be used several times as an environmental factor.

```
TVPFAC(3)=F1(XNMN,DATA3(1,1,J),NPTS3(J))                        VEG 337
```

A mineral nitrogen factor for photosynthesis is interpolated from the curve for FG J in array DATA3.

```
TVPFAC(5)=(FWVP(ZAIRR)*216.6/(ZAIRR+273.))*(1.-ZRH)             VEG 341
TVPFAC(5) = F3 (TVPFAC(5), TVPSI, DATA52(1,1,J), NR52, NC52)    VEG 342
```

Determine the photosynthesis factor depending on water vapor difference between leaf and air. TVPFAC(5) first becomes the water vapor difference between leaf and air. Leaf and air are assumed to both be at the temperature of ZAIRR. The units of FWVP are mb, while water vapor density is measured in $g \cdot m^{-3}$.

```
X = AMIN1( TVPFAC(2), TVPFAC(3), TVPFAC(5))                     VEG 344
```

X is chosen to be the minimum of the three factors determined above.

```
TVPFAC(7)=F1(ZSUN, DATA9, NPTS9(1))                             VEG 347
X=X*TVPFAC(7)                                                   VEG 348
```

X is modified by a factor determined by the fraction of possible sunlight.

```
      CALL VPHEN( J, PMDT, PMFGPS, PMJDAT, TVPP, ZZ, DRGFLG)        VEG 353
      NNN=TVPP(J)                                                   VEG 356
```

The phenophase of the current FG is determined and set equal to NNN.

```
      CVPHS(J)=0.                                                   VEG 366
      DO 80 K=1,5                                                   VEG 367
   80 CVPHS(J)=CVPHS(J)+.74*X*XVPLNT(J,K)*PVPRAT(J,K,NNN)*ZPHPD*    VEG 368
     1 PMDT                                                         VEG 369
```

These lines determine net photosynthesis during the daylight hours of a time-step. The DO loop is a sum over above-ground plant parts. The increment from each part is equal to the product of the following factors: .74, to convert kg of CO_2 fixed to kg of plant biomass; X, the photosynthesis factor depending on air temperature, SWP, the relative humidity, soil mineral nitrogen content and relative amount of sunlight determined above; XVPLNT (J,K), dry weight in kg of part K of FG J; PVPRAT (J,K, NNN), the photosynthesis rate in $kg \cdot kg^{-1} \cdot hr^{-1}$ of part K of FG J for current phenophase; ZPHPD, the average daily photoperiod in $hr \cdot day^{-1}$ during the time-step; and PMDT, length of the time-step in days.

```
      X = ZAIRT - .35*(ZAIRT-ZTMIN)                                 VEG 386
      TRRFAC = F3(X, TVPSI, DATA53(1,1,J), NR53, NC53)              VEG 387
      IF(TRRFAC .LT. 0.) TRRFAC=0.0                                 VEG 38R
      T=0.0                                                         VEG 39n
      DO 100 K=1,5                                                  VEG 391
  100 T=T + .74*XVPLNT(J,K)*TRRFAC*PVRRAT(J,K,NNN)*(24.-ZPHPD)*PMDT  VFG 392
```

Determine respiration of photosynthesizing parts during the dark hours of PMDT. X becomes a temperature slightly below average. TRRFAC is a respiration factor $\geqslant 0$, the value of which is interpolated from the family of curves in array DATA53 for FG J corresponding to air temperature X and SWP TVPSI. Line 392 parallels line 368 closely. The differences here are TRRFAC for X, PVRRAT for PVPRAT and 24—ZPHPD instead of ZPHPD.

```
      TVSOLT=0.                                                     VEG 395
      TVPS2=0                                                       VEG 396
      DO 110 K=2,PMLYRS+1                                           VEG 397
      TVPS2=TVPS2+TVPSI*CVRDST(J,K-1)                               VEG 398
  110 TVSOLT=TVSOLT+XHSOLT(K)*CVRDST(J,K-1)                         VEG 399
```

Set up root respiration calculation by averaging soil temperature and SWP weighted with respect to root distribution of FG J.

```
      TVRFAC = F3 (TVSOLT, TVPS2, DATA53(1,1,J), NR53, NC53)        VEG 401
      IF (TVRFAC .LT. 0.) TVRFAC=0.                                 VEG 402
```

Find root respiration factor TVRFAC, using function F3, at temperature TVSOLT and SWP TVPS2.

```
      TVRSPR = .74*XVPLNT(J,6)*TVRFAC*PVRRAT(J,6,NNN)*24.*PMDT      VEG 404
```

Calculate TVRSPR, which here is root respiration for all hours of PMDT, by scheme entirely parallel to that in lines 392 and 368.

```
      TVRSPR=TVRSPR+T
```

VEG 405

Here, TVRSPR becomes the sum of respiration of photosynthesizing parts during darkness and respiration of roots during all hours.

```
      CUMPSN(J)=CUMPSN(J)+CVPHS(J)
      CUMRSP(J)=CUMRSP(J)+TVRSPR
```

VEG 407
VEG 408

Keep running sums from January 1 of photosynthesis and respiration as calculated above.

```
      CALL VTRANS
```

VEG 423

Determine transpiration occurring during the time-step. The amount is passed to the water submodel which then removes it from the soil.

```
      CALL VGROW
```

VEG 430

Partition the photosynthate among the various plant parts.

```
      CALL VDETH
```

VEG 476

Determine death rates and death amounts. Then add these amounts to appropriate litter categories and subtract them from plant part categories.

```
  200 CONTINUE
```

VEG 481

This is the end of the main loop of the program.

```
      X=PVCOV*(XVTOTL**.66667)
      CVVCOV=1.-(1.-CVVCOV)*(1.-X)
```

VEG 513
VEG 514

X is the fraction of soil surface covered by perennial vegetation. CVVCOV is the fraction of soil surface covered by perennial vegetation and by whatever else went into value of CVVCOV passed to VEG. The submodel simulating annual vegetation can be called before or after VEG (or not at all). Each time-step CVVCOV is finally used by subroutine EVAP to determine evaporation from soil after which CVVCOV is reset to zero.

```
      ENTRY VINIT
```

VEG 530

This entry point is called once from MAIN for initialization purposes.

```
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
      WRITE(6,260)
```

VEG 571
VEG 572
VEG 573

Read a comment card, write it out and space. Typically it will read: INITIALIZATION DATA FOR VEG.

```
      READ(5,240) RCHECK                                                VEG 575
      WRITE(6,250) RCHECK                                               VEG 576
      READ(5,/) DEBUG3                                                  VEG 577
      WRITE(6,/) DEBUG3                                                 VEG 578
      WRITE(6,260)                                                      VEG 579
```

Read and write a comment describing DEBUG3, the variable about to be read. Read and write DEBUG3 and then space. Perform similar read and write operations for the rest of the set of variables peculiar to VEG.

```
      CALL VPINIT( J, PMDT, PMFGPS, PMJDAT, TVPP,ZZ)                    VEG 714
      CALL VGINIT                                                       VEG 715
      CALL VDINIT                                                       VEG 716
      CALL VTINIT                                                       VEG 717
```

Call initialization sections of subroutines supporting VEG, i.e., VPHEN, VGROW, VDETH, VTRANS.

Subroutine VPHEN

Table A-2 gives the definitions of variables for this subroutine.

```
      IF(PMJDAT .GE. PMDT) GO TO 20                                     VPHN 096
      DO 10 I=1,PMFGPS                                                  VPHN 097
   10 TVMDD(I) = 0.0                                                    VPHN 098
   20 CONTINUE                                                          VPHN 099
```

Reset TVMDD at January 1 each year.

```
      TVMDD(J) = TVMDD(J) + ZZ*PMDT                                     VPHN 102
```

Keep a running sum of moisture degree-days.

```
      IF((TVA(J) .GT. 1) .OR. ((TVA(J) .EQ. 1) .AND. (PMJDAT .LE. 175)))VPHN 105
     1    GO TO 30                                                      VPHN 106
      NNN = 1                                                           VPHN 107
      TVPP(J) = 1                                                       VPHN 108
```

Don't allow switch into phenophase (PHPH) 2 late in the year. Test performed by IF is false only if current PHPH is 1 and Julian date .GT. 175. When this happens, no further tests to determine PHPH switching are made. This ensures the FG's returning to PHPH 1 in the fall cannot advance through any more PHPH's until after January 1.

```
      TV = FTAVE( PMDT, 10)                                             VPHN 112
```

Determine TV, average temperature for the previous 10 days.

```
      NNN=TVA(J)                                                        VPHN 113
```

Set present PHPH equal to NNN.

Table A-2. Variable dictionary for VPHEN

FLAG	LOGICAL VARIABLE WHICH EQUALS .TRUE. IF PH. PH. OF CURRENT FG IS TO BE INCREASED BY 1 THIS TIME STEP.
FTAVE (PMDT,10)	FUNCTION WHICH CALCULATES AVERAGE AIR TEMPERATURE FOR PREVIOUS 10 DAYS GIVEN THAT THE TIME STEP LENGTH HAS BEEN OF LENGTH PMDT.
NNN	CURRENT PH.PH. OF CURRENT FG. IT IS EQUAL TO, AND MUCH EASIER TO PUNCH THAN TVPP(J).
PMJDAT	CURRENT JULIAN DAY
PVENV (J,NNN)	ENVIRONMENTAL INDEX PARAMETER FOR FG J IN PH.PH. NNN. THE LAST OF THREE TESTS WHICH MUST BE MET FOR ENVIRONMENTAL COMBINATION FACTOR TO SWITCH PH.PH. IS ZZ.GE PVENN (J,NNN).
PVJD (J,NNN)	JULIAN DAY FACTOR FOR FG J WHEN ITS PH.PH. IS NNN. THAT IS, IF PMJDAT IS GREATER THAN OR EQUAL TO PVJD(J,NNN),THEN NNN IS INCREMENTED TO THE NEXT PH.PH.
PVMDD (J,NNN)	MOISTURE- DEGREE DAY PARAMETER FOR FG J IN PH.PH. NNN. THE FIRST OF THREE TESTS WHICH MUST BE MET IF ENVIRONMENTAL COMBINATION FACTOR IS TO SWITCH PH.PH. IS TVMDD(J) .GE. PVMDD(J,NNN).
PVTMIN(J,NNN)	MINIMUM TEMPERATURE FACTOR FOR FG J WHEN ITS PH.PH. IS NNN. IF GREATER THAN OR EQUAL TO TV, SWITCH TO NEXT PH.PH.
PVTV(J,NNN)	TEMPERATURE PARAMETER FOR FG J IN PH.PH. NNN. THE SECOND OF THREE TESTS WHICH MUST BE MET IF ENVIRONMENTAL COMBINATION FACTOR IS TO SWITCH PH.PH. IS TV .GE. PVTL(J,NNN).
TV	AVERAGE AIR TEMPERATURE DURING PREVIOUS TEN DAYS, DEGREES CELSIUS
TVA(J)	PHENOPHASE OF FG J AT BEGINNING OF EXECUTION OF SUBROUTINE VPHEN
TVDAY(J)	AN INTEGER VARIABLE, USED FOR DEBUGGING, WHICH STORES THE JULIAN DATE OF THE PH.PH. SWITCH OF FG J.
TVMDD(J)	RUNNING SUM FROM JANUARY 1 OF MOISTURE DEGREE DAYS FOR FG J, DAY.
TVPP(J)	CURRENT PH.PH. OF FG J
TVSW(J)	AN INTEGER VARIABLE, USED FOR DEBUGGING PURPOSES, WHICH INDICATES THE TEST WHICH CAUSED THE PH.PH. OF FG J TO CHANGE. EQUALS 4 IF JULIAN DAY FACTOR CAUSED SWITCH, 2 IF MINIMUM TEMPERATURE, 1 IF ENVIRONMENTAL COMBINATION. IF MORE THAN ONE FACTOR COULD HAVE CAUSED SWITCH, TVSW(J) IS SUM OF INDIVIDUAL INDICES. E.G. IF ALL FACTORS SAY SWITCH THEN TVSW(J)=7.
ZZ	ENVIRONMENTAL INDEX GENERATED IN VEG. VARIES BETWEEN 0 (UNFAVORABLE FOR GROWTH) AND 1 (OPTIMAL FOR GROWTH).

```
      FLAG=.FALSE.                                                      VPHN 118
```

If FLAG is set equal to .TRUE. during any or all of the next three tests, PHPH for the current FG is advanced.

```
      IF(PMJDAT .GE. PVJD(J,NNN)) GO TO 40                              VPHN 121
      GO TO 50                                                          VPHN 122
   40 FLAG=.TRUE.                                                       VPHN 123
```

This is a switch based on Julian date.

```
   50 IF(TV .LT. PVTMIN(J,NNN)) GO TO 60                                VPHN 127
      GO TO 70                                                          VPHN 128
   60 FLAG=.TRUE.                                                       VPHN 129
```

Minimum temperature switch. If average temperature is too cold, PHPH is advanced. This will probably be the main switch when NNN equals 4 or 5.

```
   70 IF ((TVMDD(J) .GE. PVMDD(J,NNN)) .AND. (TV .GE. PVTL(J,NNN))      VPHN 133
     1   .AND. (ZZ .GE. PVENV(J,NNN))) GO TO 80                         VPHN 134
      GO TO 90                                                          VPHN 135
   80 FLAG=.TRUE.                                                       VPHN 136
```

Environmental combination switch. If all three tests here are met, conditions are good enough to advance PHPH. The first test is to determine if enough moisture degree-days have accumulated. The second is to assure that the average air temperature is warm enough. The third is to see that ZZ (a moisture-temperature combination factor) is favorable enough.

```
      IF(FLAG) NNN=NNN+1                                                VPHN 141
```

Here is where PHPH is actually advanced.

```
      ENTRY VPINIT( J, PMDT, PMFGPS, PMJDAT, TVPP, ZZ)                  VPHN 157
```

Entry point VPINIT is called once from VEG for initialization purposes. Because there are no common blocks in VPHEN, argument lists are used in calls to VPHEN and VPINIT. The READ and WRITE statements are set up in just the same way as in VEG.

Subroutine VGROW

Table A-3 defines variable names for this subroutine. The abbreviations used are the same as those previously used.

```
      TVNET=CVPHS(J) - TVRSPR                                           VGRO 095
      TVNP=TVNET                                                        VGRO 096
```

Calculate net photosynthate to be allocated for current FG. TVNET will be decreased as it is allocated. TVNP holds initial value.

Table A-3. Variable dictionary for VGROW

ABBREVIATIONS COMMONLY USED ARE FG FOR FUNCTIONAL GROUP AND PHPH FOR PHENOPHASE.

A(I)	FRACTION OF TVNPS PLANT PART I WILL GET, DIMENSIONLES
CVPHS(J)	NET PHOTOSYNTHATE PRODUCTION OF FG J DURING DAYLIGHT PART OF TIMESTEP, KG HA-1
J	INDEX OF CURRENT FG
NNN	PH.PH. OF FG J
PHOT	TIMESTEP LENGTH, DAY.
PVHT(FG,PP,PHPH)	HALF TIMES REQUIRED FOR PLANT TO BUILD UP PART (LEAVES, FRUITS, FLOWERS) UNDER OPTIMUM CONDITIONS
PVLR(FG,I)	FACTORS LEAVES AND REPRODUCTIVE PARTS ARE MULTIPLIED BY IN ALLOCATING NEGATIVE TVNET.
PVPF(FG,PP,PHPH,1&2)	INTERCEPT AND SLOPE OF LINE WITH ENV. INDEX AS INDEPENDENT VARIABLE TO DETERMINE PROPORTIONALITY FACTOR FOR ALLOCATION OF REMAINDER OF TVNET. DEPENDS ON FG, PP, AND PHPH.
PVPROP(FG,PP,PHPH,1&2)	INTERCEPT AND SLOPE OF LINE WITH ENVIRONMENTAL INDEX AS INDEPENDENT VARIABLE TO DETERMINE ALLOCATION PROP. FOR 1ST 5 PLANT PARTS
PVRSA(FG,K,L)	ROOT SHOOT ALLOCATION RATIO AS IT DEPENDS ON PHENOPH.
RS	ROOT - SHOOT ALLOCATION RATIO FOR PRESENT F.G. THIS TIME STEP, DIMENSIONLESS.
RSTOT	ROOT - SHOOT RATIO OF TOTALS ALLOCATED THIS YEAR TO ALL F.G.'S.
RTOT	TOTAL ALLOCATED TO ROOTS OF ALL F.G.'S SINCE JANUARY 1, KG HA-1.
SSUM	TOTAL ALLOCATED ABOVE GROUND THIS TIME STEP TO PRESENT F.G. KG HA-1.
STOT	TOTAL ALLOCATED TO SHOOTS OF ALL F.G.'S SINCE JANUARY 1, KG HA-1.
T(1)	ALLOCATION TO PART 1 THIS TIME STEP OF PRESENT F.G. IN ORDER TO BRING IT UP TOWARD NOMINAL LEVEL, KG HA-1
TSUM	SUM OVER I OF T(I), KG HA-1.
TVNET	REMAINING PHOTOSYNTHATE TO ALLOCATE, KG HA-1
TVNP	NET PHOTOSYNTHATE FOR PRESENT F.G., TIME STEP, KG HA-1
TVNPR	ROOTS' SHARE OF TVNP AFTER REMOVAL OF T(I)'S, KG HA-1
TVNPS	SHOOTS' SHARE OF TVNP AFTER REMOVAL OF T(I)'S, KG HA-1
TVRSPR	RESPIRATION OF FG J, KG HA-1
X	TEMPORARY VARIABLE
XP	NOMINAL PROPORTION OF TOTAL BIOMASS OF FG J FOR PP I.
XVPLNT(J,I)	BIOMASS OF PP I OF FG J, KG HA-1.
Y	AMOUNT OF BIOMASS INCREMENT NEEDED BY PP I IN ORDER FOR IT TO REACH NOMINAL PROPORTION XP.
Z	LARGEST PORTION OF Y WHICH WILL BE ALLOWED TO BE ALLOCATED
ZZ	ENVIRONMENTAL INDEX WHICH VARIES FROM 0 (UNFAVORABLE FOR GROWTH) TO 1 (FAVORABLE FOR GROWTH).

```
      X=0.0                                   VGRO 101
      DO 10 I=1,6                             VGRO 102
   10 X = X + XVPLNT(J,I)                     VGRO 103
```

Determine total biomass of current FG and call it X.

```
      DO 20 I=1,5                             VGRO 106
```

DO loop over PP.

```
      XP = PVPROP(J,I,NNN,1) + ZZ * PVPROP(J,I,NNN,2)     VGRO 108
      Y = X * XP - XVPLNT(J,I)                            VGRO 109
      IF(Y .LT. 0.0) Y=0.0                                VGRO 112
```

XP is the nominal proportion of total biomass X of current PP. It depends on FG J, PP I, PHPH NNN and environmental index ZZ. Y is the biomass increment needed by PP I if it is to reach its nominal proportion XP. Y is not allowed to be negative.

```
      Z = 1. - EXP(-.693147*PMDT / PVHT(J,I,NNN))         VGRO 114
```

Since growth cannot occur instantaneously, determine Z, the largest fraction of Y which can be allocated. Z depends on length of time-step, PMDT and a "half-time" PVHT, which itself depends on FG, PP and PHPH.

```
      T(I) = Y * Z * ZZ                                   VGRO 116
      XVPLNT(J,I) = XVPLNT(J,I) + T(I)                    VGRO 118
```

The amount allocated to PP I in bringing it up toward its nominal proportion is T(I), which is the product of Y, Z and ZZ.

```
      X = PVRSA(J,1,NNN) + ZZ * PVRSA(J,2,NNN)            VGRO 126
      TVNPR = (X/(X+1.)) * TVNET                          VGRO 128
      XVPLNT(J,6) = XVPLNT(J,6) + TVNPR                   VGRO 129
```

The nominal root:shoot allocation ratio, X, for FG J, PHPH NNN and environmental index ZZ is found using the parameters in array PVRSA. The roots' share of the remainder of the net photosynthate to be allocated is TVNPR. The shoots' share is thus TVNET — TVNPR. Their ratio is X, i.e.:

$$X = TVNPR/(TVNET - TVNPR) \qquad \text{(A-2)}$$

If Equation A-2 is solved for TVNPR, one gets line 128. The next line shows the root compartment being incremented.

```
      X=0.0                                                          VGRO 134
      DO 30 I=1,5                                                    VGRO 135
      A(I)=(PVPF(J,I,NNN,1) + ZZ*PVPF(J,I,NNN,2)) * XVPLNT(J,I)      VGRO 136
   30 X = X + A(I)                                                   VGRO 137
      IF(X .LT. .001) X=.001                                         VGRO 138
      X=1./X                                                         VGRO 140
      DO 40 I=1,5                                                    VGRO 141
   40 A(I)=A(I)*X                                                    VGRO 142
```

X is a proportionality factor. A(I) is proportional to the amount of photosynthate which is about to be allocated to shoot part I (for shoots, I = 1,2,3,4,5). Remember that at this point, all of the material to be allocated is going to the shoots. The first time A(I) is calculated, it is proportional to the biomass of PP I of FG J and a proportionality factor which depends on environmental conditions, PHPH, PP and J. X first becomes the sum of A(I) -- it is not allowed to get less than .001. X is then inverted in order to get the proportionality factor needed. When each A(I) is multiplied by the final X, then the resulting A(I) values will sum to 1. If somehow the sum of the original A(I) values was less than .001, then not all of the remaining photosynthate will be allocated.

```
      IF(TVNET .GE. 0.0) GO TO 80
```

VGRO 147

If TVNET is less than zero, allocation will actually be removing material.

```
      DO 50 I=1,3
   50 A(I)=A(I)*PVLR(J,I)
      X=0.0
      DO 60 I=1,5
   60 X = X + A(I)
      IF(X .LE. 1.E-4)  X=1.E-4
      DO 70 I=1,5
   70 A(I)=A(I)/X
```

VGRO 149
VGRO 150
VGRO 151
VGRO 152
VGRO 153
VGRO 154
VGRO 155
VGRO 156

We reach here only if TVNET is less than zero. These lines adjust array A(I) in order to favor certain organs, leaves and reproductive organs; e.g., first A(I) is multiplied by PVLR (J,I), which might be 1.0 for stems but only 0.2 for leaves. Then, A(I) is normalized as above in order to get the sum of A(I) equal to 1.

```
      ENTRY VGINIT
```

VGRO 202

Entry point VGINIT is called once from VEG for initialization purposes. The READ and WRITE statements are set up in just the same way as in VEG.

Subroutine VTRANS

Table A-4 defines variable names for subroutine VTRANS.

```
      TVWVD = FWVP(ZAIRR) * (1.-ZRH)
```

VTRN 052

Determine water vapor pressure difference between leaf and air (in mb).

```
      TVPT = PVPT(1) + PVPT(2) * TVWVD
```

VTRN 055

Find uncorrected photosynthesis to transpiration ratio (P:T). This is the correct ratio if the temperature is optimum.

Table A-4. Variable dictionary for VTRANS

```
CVTSPR(J,L)TRANSPIRATION OF FG J FROM SOIL LAYER L, KG WATER HA-1

DATA        ARRAY STORING PAIRS OF DATA POINTS FOR RELATIONSHIP
            BETWEEN FACTOR F AND DIFFERENCE BETWEEN ACTUAL AND
            OPTIMUM TEMPERATURE.

F           FACTOR TO "CORRECT" P/T RATIO FOR DIFFERENCE BETWEEN
            ACTUAL AND OPTIMUM TEMPERATURE.

F1          FUNCTION WHICH INTERPOLATES OVER SINGLE INDEPENDENT
            VARIABLE.

FWVP(T)     FUNCTION WHICH DETERMINES SATURATED WATER VAPOR PRESSURE
            AT TEMPERATURE (IN DEGREES CELSIUS) T, MB.

NPTS        NUMBER OF PAIRS OF DATA POINTS IN ARRAY DATA.

PVPT(1&2)   PARAMETERS OF STRAIGHT LINE GIVING RELATIONSHIP BETWEEN
            P/T AND WATER PRESSURE VAPOR DIFFERENCE BETWEEN LEAF
            AND AIR.

TVPT        P/T-RATIO OF PHOTOSYNTHESIS (KG CO2 HA-1) TO
            TRANSPIRATION (KG WATER HA-1)

TVTCOR      DIFFERENCE BETWEEN 20 DEGREES CELSIUS AND CURRENT OPTIMUM
            TEMPERATURE FOR FG J. CALCULATED IN VEG, DEGREES CELSIUS.

TVWVD       WATER VAPOR PRESSURE DIFFERENCE BETWEEN LEAF AND AIR, MB.

X           DIFFERENCE BETWEEN ACTUAL AND OPTIMUM TEMPERATURE DEGREES
            CELSIUS.

ZAIRR       AVERAGE TIME STEP AIR TEMPERATURE, DETERMINED IN PSWG,
            DEGREES CELSIUS.

ZRH         AVERAGE TIME STEP RELATIVE HUMIDITY, DETERMINED IN
            PSWG, DECIMAL FRACTION BETWEEN 0 AND 1.
```

```
X = ZAIRR - (20. - TVTCOR)                                    VTRN 059
F = F1(X, DATA, NPTS)                                         VTRN 061
```

Calculate the difference, X, between actual and optimum temperature for FG J. Use this difference to determine "correction" factor, F, to P:T. At Curlew Valley, for example, if the optimum is 10 C above air temperature, F = 2.

```
TVPT = TVPT * F                                               VTRN 062
IF((TVPT .GT. .030) .OR. (TVPT .LT. .0005)) TVPT = .009       VTRN 065
```

"Correct" P:T and make sure the value is reasonable.

```
CVTSPR(J,1) = ABS(CVPHS(J) / (.74 * TVPT) )                   VTRN 072
```

Calculate the amount of transpiration in kg $H_2O \cdot ha^{-1}$. Recall that CVPHS (J)/.74 is the amount of photosynthesis of FG J in kg $CO_2 \cdot ha^{-1}$ taken up (CVPHS(J) is in kg dry biomass$\cdot ha^{-1}$). At this point, transpiration is assumed to be entirely taken from layer 1. WATER determines the layer(s) from which transpiration is actually taken.

```
ENTRY VTINIT                                                  VTRN 081
```

This entry point is called once from VEG for initialization purposes. The READ and WRITE statements are set up in just the same way as in VEG.

Table A-5. Variable dictionary for VDETH

CVRDST (J,L)	ROOT DISTRIBUTION IN LAYER L OF FG J, THE SUM OVER L FOR EACH J EQUALS 1.
PMDT	LENGTH OF TIME STEP, DAY.
PVDTH(FG, PP, PHPH, ENV)	INSTANTANEOUS DEATH RATES AS FUNCTIONS OF FUNCTIONAL GROUP, PLANT PART, PHENOLOGICAL INDEX, ENVIRONMENTAL INDEX, DAY-1.
PVRSB(FG,PHPH,1+2)	PARAMETERS OF STRAIGHT LINE DEPENDENT ON ENVIRONMENTAL INDEX GIVING ROOT - SHOOT BIOMASS RATIO WHICH PLANT TRIES TO REACH BY FUNCTIONAL GROUP AND PHENOPHASE.
TVDETH (K)	NOMINAL INSTANTANEOUS DEATH RATE OF PLANT PART K, DAY-1
TVDTH(K)	AMOUNT OF PP K DYING THIS TIME STEP, KG HA-1.
X	TOTAL SHOOT BIOMASS OF FG J, KG HA-1.
XVLITR(L,M)	LITTER AMOUNT IN LOCATION L (STANDING, SOIL SURFACE UP TO 8 SOIL LAYERS) OF TYPE M (FECES, SOFT, HARD, WOODY), KG HA-1.
XVPLNT(J,K)	DRY WEIGHT BIOMASS OF PP K OF FG J, KG HA-1.
Y	CURRENT ROOT-SHOOT RATIO OF FG J.
Z	NOMINAL ROOT-SHOOT RATIO.
ZZ	ENVIRONMENTAL INDEX CALCULATED IN VEG. EQUALS 0 IF CONDITIONS UNFAVORABLE FOR GROWTH, EQUALS 1 FOR IDEAL CONDITIONS.

SUBROUTINE VDETH

Table A-5 defines variable names for this subroutine.

```
      DO 10 K=1,6                                           VDTH 051
      TVDETH(K) = PVDTH(J,K,NNN,1) - ZZ*PVDTH(J,K,NNN,2)    VDTH 052
   10 IF(TVDETH(K) .LT. 0.0)  TVDETH(K)=0.0                 VDTH 053
```

Determine nominal instantaneous death rate for PP K of FG J. It depends on PHPH and environmental conditions.

```
      X=0.0                                                 VDTH 059
      DO 20 K=1,5                                           VDTH 060
   20 X = X + XVPLNT(J,K)                                   VDTH 061
      IF(X .LT. 5.) X=5.                                    VDTH 062
      Y=XVPLNT(J,6)/X                                       VDTH 063
```

Determine the current root:shoot ratio.

```
      Z = PVRSB(J,NNN,1) - ZZ * PVRSB(J,NNN,2)              VDTH 066
```

Determine the nominal root:shoot ratio.

```
      TVDETH(6)=TVDETH(6) * Y / Z                           VDTH 068
```

Adjust the root death rate in order to help bring the root:shoot ratio toward nominal value.

```
      DO 30 K=1,6                                           VDTH 072
   30 TVDTH(K)=XVPLNT(J,K) * (1. - EXP(-TVDETH(K)*PMDT))    VDTH 073
```

Determine the amount of PP K dying this time-step.

```
      ENTRY VDINIT                                            VDTH 099
```

This entry point is called once from VEG for initialization purposes. The READ and WRITE statements are set up in just the same way as in VEG.

FUNCTION FWVP

```
      FWVP=EXP(1.81337 + 0.0714*T - 0.00023*T*T)              FWVP 13
```

Given temperature in degrees Celcius, this equation gives the saturation water vapor pressure in mb. "True" values were taken from Smithsonian Meteorological Tables, page 352 (List 1949). At —5 C, the equation gives a value 1.4% high. Between 0 C and 45 C, the equation varies between extremes of .29% low and .33% high. At 50 C, it is .71% low.

COMPLETE PROGRAM LISTING

Subroutine VEG

```
      SUBROUTINE VEG
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C                                SUBROUTINE VEG
C
C  WRITTEN BY     DONOVAN C. WILKIN AND PAUL W. LOMMEN
C                 DESERT BIOME - ECOLOGY CENTER  UMC 52
C                 UTAH STATE UNIVERSITY
C                 LOGAN, UTAH 84322
C
C    AUGUST 1976
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C  THIS SUBROUTINE SIMULATES PERENNIAL PLANT BIOMASS.    IT IS
C  PARAMETERIZED SO THAT THE DYNAMICS OF EACH OF THE DESERT BIOME
C  RESEARCH SITES CAN BE SIMULATED.  FUNCTIONAL GROUPS RATHER THAN
C  SPECIES ARE SIMULATED.  ORGANS TRACKED ARE LEAF, FRUIT, FLOWER,
C  NEW STEM, OLD STEM, AND ROOT.
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C                           VARIABLE DICTIONARY
C
C  CAAR(J,K)   AMOUNT OF PLANT PART K, FUNCTIONAL GROUP J, INGESTED
C              BY ANIMALS DURING THE TIME STEP, KG HA-1.
C
C  CADEST(J,K)  AMOUNT OF LIVE PLANT PART K, FUNCTIONAL GROUP J,
C              TRANSFERRED BY ANIMAL ACTIVITY FROM PLANT TO SURFACE
C              LITTER DURING TIME STEP, KG HA-1.
C
C  CUMPSN(J)   ACCUMULATED PHOTOSYNTHATE PRODUCTION FROM JANUARY 1
C              FOR FUNCTIONAL GROUP J, KG HA-1.
C
C  CUMRSP(J)   ACCUMULATED RESPIRATORY LOSSES FROM JANUARY 1 FOR
C              FUNCTIONAL GROUP J, KG HA-1.
C
C  CUMTRP(J)   ACCUMULATED TRANSPIRATION FOR FUNCTIONAL GROUP J
C              FROM JANUARY 1, KG HA-1.
C
C  CVPHS(J)    NET PHOTOSYNTHATE PRODUCTION OF FUNCTIONAL GROUP J
C              DURING THE DAYLIGHT PART OF THE TIMESTEP, KG HA-1.
C
C  CVRDST(J,K)  FRACTION OF TOTAL ROOT BIOMASS OF FUNCTIONAL GROUP J
C              FOUND IN SOIL LAYER K, 0 TO 1.
C
C  CVTSPR(J,K)  WATER TRANSPIRED FROM SOIL LAYER K BY FUNCTIONAL
C              GROUP J DURING THE TIME STEP, KGWATER HA-1.
C
C  CVVCOV      FRACTION OF SOIL SURFACE COVERED BY VEGETATION, 0 TO 1.
C
C  CWPSI(K)    SOIL WATER POTENTIAL IN SOIL LAYER K, BAR.
C
C  D           TEMPORARY VARIABLE USED IN ANIMAL REMOVAL SECTION.
C
C  DATA1(L,2,J)  DATA PAIRS (L IN NUMBER) RELATING AVERAGE
C              AIR TEMPERATURE TO OPTIMUM PHOTOSYNTHESIS AIR
C              TEMPERATURE (BOTH DEGREES CELSIUS) FOR
C              FUNCTIONAL GROUP J.
C
C  DATA3(L,2,J)  DATA PAIRS (L IN NUMBER) FOR FUNCTIONAL GROUP J,
C              RELATING SOIL MINERAL NITROGEN CONCENTRATIONS IN KG HA-1
C              TO A PHOTOSYNTHESIS SCALING FACTOR, 0 TO 1.
C
C  DATA9(L,2)  DATA PAIRS (L IN NUMBER) RELATING THE FRACTION OF
C              POSSIBLE SUNLIGHT HOURS DURING THE PHOTOPERIOD TO A
C              SCALING FACTOR FOR PHOTOSYNTHESIS, 0 TO 1.
C
C  DATA51(NR51,NC51,J)    ARRAY CONTAINING A 2-DIMENSIONAL MATRIX FOR
C              EACH FUNCTIONAL GROUP  J FOR USE WITH FUNCTION F3.  EACH
C              2-DIMENSIONAL MATRIX HAS NR51 ROWS AND NC51 COLUMNS AND
C              IS A FAMILY OF RELATIVE NET PHOTOSYNTHESIS VS.
C              TEMPERATURE CURVES FOR VARIOUS VALUES OF SOIL WATER
C              POTENTIAL.
C
C  DATA52(NR52,NC52,J)    ARRAY CONTAINING A 2-DIMENSIONAL MATRIX FOR
C              EACH FUNCTIONAL GROUP  J FOR USE WITH FUNCTION F3.  EACH
C              2-DIMENSIONAL MATRIX HAS NR52 ROWS AND NC52 COLUMNS AND
C              IS A FAMILY OF RELATIVE NET PHOTOSYNTHESIS VS.
C              SOIL WATER POTENTIAL CURVES FOR DIFFERENT VALUES OF
C              WATER VAPOR DENSITY DIFFERENCE BETWEEN LEAF AND AIR.
C
C  DATA53(NR53,NC53,J)    ARRAY CONTAINING A 2-DIMENSIONAL MATRIX FOR
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```
C               EACH FUNCTIONAL GROUP  J FOR USE WITH FUNCTION F3.  EACH C
C               2-DIMENSIONAL MATRIX HAS NR53 ROWS AND NC53 COLUMNS AND  C
C               IS A FAMILY OF RELATIVE DARK RESPIRATION VS. TEMPERATURE C
C               CURVES FOR VARIOUS VALUES OF SOIL WATER POTENTIAL.       C
C                                                                        C
C   DBGFLG      LOGICAL DEBUGGING FLAG.  IF EQUALS .TRUE. DEBUGGING      C
C               INFORMATION IS WRITTEN THIS TIME STEP.                   C
C                                                                        C
C   DEBUG3      PRESET TO A VALUE 'N', PRINTS DEBUGGING INFORMATION      C
C               EVERY N-TH TIME STEP BEGINNING WITH TIME STEP NUMBER ONE.C
C                                                                        C
C   DT          EQUALS PMDT. LENGTH OF TIMESTEP, DAY.                    C
C                                                                        C
C   F1          A ONE DIMENSIONAL INTERPOLATION FUNCTION.                C
C                                                                        C
C   F3          TWO DIMENSIONAL INTERPOLATION FUNCTION.                  C
C                                                                        C
C   FTAVE(PMDT,N)  FUNCTION TO AVERAGE PREVIOUS N DAYS' AIR              C
C               TEMPERATURES BY AVERAGING APPROPRIATE NUMBER             C
C               OF PREVIOUS TIME STEP AVERAGE TEMPERATURES.              C
C                                                                        C
C   FWVP(T)     FUNCTION WHICH, GIVEN T IN DEGREES CELSIUS,              C
C               CALCULATES SATURATION WATER VAPOR PRESSURE IN MB.        C
C                                                                        C
C   I           INDEX VARIABLE.                                          C
C                                                                        C
C   J           USED AS PLANT FUNCTIONAL GROUP SUBSCRIPT.                C
C                                                                        C
C   K           USED VARIOUSLY AS PLANT PART SUBSCRIPT, OR SOIL LAYER    C
C               SUBSCRIPT.                                               C
C                                                                        C
C   L           INDEX VARIABLE.                                          C
C                                                                        C
C   M           INDEX VARIABLE USED TO INDICATE LITTER LOCATION.         C
C                                                                        C
C   N           USED AS SUBSCRIPT OF WETTEST SOIL LAYER.                 C
C                                                                        C
C   NC51        NUMBER OF COLUMNS IN EACH OF THE PMFGPS 2-DIMENSIONAL    C
C               MATRICES MAKING UP THE DATA51 ARRAY.                     C
C                                                                        C
C   NC52        NUMBER OF COLUMNS IN EACH OF THE PMFGPS 2-DIMENSIONAL    C
C               MATRICES MAKING UP THE DATA52 ARRAY.                     C
C                                                                        C
C   NC53        NUMBER OF COLUMNS IN EACH OF THE PMFGPS 2-DIMENSIONAL    C
C               MATRICES MAKING UP THE DATA53 ARRAY.                     C
C                                                                        C
C   NNN         PHENOPHASE OF CURRENT PLANT GROUP.                       C
C                                                                        C
C   NPTS1(J)    NUMBER OF DATA PAIRS IN DATA1, FUNCTIONAL GROUP J.       C
C                                                                        C
C   NPTS3(J)    NUMBER OF DATA PAIRS IN DATA3 FOR FUNCTIONAL GROUP J.    C
C                                                                        C
C   NPTS9(1)    NUMBER OF DATA PAIRS IN DATA9.                           C
C                                                                        C
C   NR51        NUMBER OF ROWS IN EACH OF THE PMFGPS 2-DIMENSIONAL       C
C               MATRICES MAKING UP THE DATA51 ARRAY.                     C
C                                                                        C
C   NR52        NUMBER OF ROWS IN EACH OF THE PMFGPS 2-DIMENSIONAL       C
C               MATRICES MAKING UP THE DATA52 ARRAY.                     C
C                                                                        C
C   NR53        NUMBER OF ROWS IN EACH OF THE PMFGPS 2-DIMENSIONAL       C
C               MATRICES MAKING UP THE DATA53 ARRAY.                     C
C                                                                        C
C   PMDT        LENGTH OF TIMESTEP, DAY.                                 C
C                                                                        C
C   PMFGPS      NUMBER OF PLANT FUNCTIONAL GROUPS BEING SIMULATED.       C
C                                                                        C
C   PMJDAT      JULIAN DATE OF THE CURRENT TIME STEP.                    C
C                                                                        C
C   PMJDAY      JULIAN DATE OF THE CURRENT TIME STEP. EQUALS PMJDAT.     C
C                                                                        C
C   PMLYRS      NUMBER OF SOIL LAYERS BEING SIMULATED.                   C
C                                                                        C
C   PVCOV       PARAMETER USED IN COVER CALCULATION                      C
C                                                                        C
C   PVPRAT(J,K)  MAXIMUM POSSIBLE PHOTOSYNTHESIS RATE OF PLANT PART K,   C
C               FUNCTIONAL GROUP J, KG KG-1 HR-1.                        C
C                                                                        C
C   PVRRAT(J,K)  MAXIMUM RESPIRATORY RATE OF PLANT PART K, FUNCTIONAL    C
C               GROUP J, KG KG-1 HR-1.                                   C
C                                                                        C
C   Q           TEMPORARY VARIABLE USED TO DETERMINE VALUE OF DBGFLG.    C
C                                                                        C
C   RCHECK      ARRAY USED TO READ AND WRITE COMMENTS IN INPUT DATA.     C
C                                                                        C
C   T             TEMPORARILY USED TO HOLD VALUE OF RESPIRATION OF       C
C               PHOTOSYNTHESIZING PARTS DURING DARK HOURS, KG HA-1.      C
C                                                                        C
C   TRRFAC      SCALING FACTOR FOR RESPIRATION OF PHOTOSYNTHESIZING      C
C               PARTS, DECIMAL FRACTION, 0 TO 1.                         C
```

```
C
C  TVPFAC(2)  AFTER INTERMEDIATE USE, BECOMES A SCALING FACTOR FOR
C             PHOTOSYNTHESIS RATE DEPENDING ON AIR TEMPERATURE (IN
C             DEGREES CELSIUS) AND SOIL WATER POTENTIAL (IN BARS),
C             -.3 TO 1.
C
C  TVPFAC(3)  PHOTOSYNTHESIS SCALING FACTOR DEPENDING ON SOIL MINERAL
C             NITROGEN CONCENTRATION (IN KG HA-1), 0 TO 1.
C
C  TVPFAC(5)  AFTER INTERMEDIATE USE, BECOME A SCALING FACTOR FOR
C             PHOTOSYNTHESIS RATE DEPENDING ON RELATIVE
C             HUMIDITY, 0 TO 1.
C
C  TVPFAC(7)  A SCALING FACTOR FOR PHOTOSYNTHESIS RATE DEPENDING ON
C             FRACTION OF POSSIBLE SUNLIGHT HOURS, 0 TO 1.
C
C  TVPP(J)    PHENOPHASE OF PLANT GROUP J.
C
C  TVPS1      SOIL WATER POTENTIAL IN THE WETTEST LAYER CONTAINING AT
C             LEAST 10 PER CENT OF THE ROOTS OF THE PLANT FUNCTIONAL
C             GROUP, BAR.
C
C  TVPS2      SOIL WATER POTENTIAL OF THE ROOT ZONE WEIGHTED BY ROOT
C             DISTRIBUTION, BAR.
C
C  TVRFAC     A SCALING FACTOR FOR RESPIRATION RATE  FOR ROOTS
C             AS A FUNCTION OF SOIL TEMPERATURE (IN DEGREES CELSIUS)
C             AND SOIL WATER POTENTIAL (IN BAR), 0 TO 1..
C
C  TVRSPR     DARK RESPIRATION.  EQUALS SUM OF RESPIRATION OF
C             PHOTOSYNTHESIZING PARTS DURING DARKNESS AND RESPIRATION
C             OF ROOTS FOR ALL HOURS DURING THE TIMESTEP, KG HA-1.
C
C  TVSOLT     TIME STEP AVERAGE WEIGHTED MEAN SOIL TEMPERATURE
C             WEIGHTED BY ROOT DISTRIBUTION OF THE FUNCTIONAL
C             GROUP, DEGREES CELSIUS.
C
C  TVTCOR     CORRECTION TERM FOR TEMPERATURE ACCLIMATION, DEG. CELSIUS
C
C  VDETH      DEATH SUBROUTINE. SEE WRITE-UP ON VDETH FOR DETAILS.
C
C  VGROW      GROWTH SUBROUTINE.  SEE WRITE-UP ON VGROW FOR DETAILS.
C
C  VPHEN      PHENOLOGY SUBROUTINE.  SEE WRITE-UP ON VPHEN FOR DETAILS.
C
C  VTRANS     SUBROUTINE WHICH CALCULATES TRANSPIRATION.  SEE
C             WRITE-UP ON VTRANS FOR DETAILS.
C
C  X          INTERMEDIATE VARIABLE- VARIOUSLY USED.
C
C  XHSOLT(K)  TIME STEP AVERAGE SOIL TEMPERATURE IN SOIL LAYER K-1,
C             DEGREES CELSIUS.
C
C  XNMN       SOIL INORGANIC (MINERAL) NITROGEN CONCENTRATION, KG HA-1
C
C  XVFG(J,K)  ABOVE GROUND BIOMASS OF PARTS OF FUNCTIONAL GROUP J.
C             IF K=1, IT IS LEAVES, IF K=2, IT IS ALL REPRODUCTIVE
C             STRUCTURE, IF K=3, IT IS NEW STEM, IFK=4, IT IS OLD
C             STEM, AND IF K=5, IT IS TOTAL OF ALL ABOVE GROUND
C             PLANT PARTS, KG HA-1.
C
C  XVLITR(J,K)  MASS OF LITTER OF TYPE K, IN LOCATION J.  LITTER TYPES
C             ARE (1) FECES, (2) SOFT, (3) HARD, AND (4) WOOD.
C             LITTER LOCATIONS ARE (1) STANDING DEAD, (2) GROUND
C             SURFACE, AND (3 TO N) THE DEFINED SOIL LAYERS, KG HA-1.
C
C  XVPLNT(J,K)  BIOMASS OF PLANT PART K IN PLANT FUNCTIONAL
C             GROUP J.  THE PLANT PARTS SIMULATED ARE (1) LEAF, (2)
C             FLOWER, (3) FRUIT, (4) NEW STEM, (5) OLD STEM, AND (6)
C             ROOTS, KG HA-1.
C
C  XVTOTL     TOTAL ABOVE GROUND PLANT BIOMASS, KG HA-1.
C
C  ZAIRR      VARIABLE USED TO HANG ON TO TEMPERATURE TO WHICH NET
C             PHOTOSYNTHESIS IS KEYED, DEGREES CELSIUS.
C
C  ZAIRT      AVERAGE DAILY MEAN AIR TEMPERATURE DURING TIME STEP,
C             DEGREES CELSIUS.
C
C  ZPHPD      AVERAGE DAILY PHOTOPERIOD DURING THE TIME STEP, HR DAY-1.
C
C  ZSUN       AVERAGE ACTUAL FRACTION OF POSSIBLE SUNLIGHT HOURS FOR
C             TIME STEP, 0 TO 1.
C
C  ZRH        AVERAGE 11 A.M. RELATIVE HUMIDITY DURING TIME STEP 0 TO 1
C
C  ZTMAX      AVERAGE DAILY MAXIMUM AIR TEMPERATURE DURING TIME STEP,
C             DEGREES CELSIUS .
C
C  ZTMIN      AVERAGE DAILY MINIMUM AIR TEMPERATURE DURING TIME STEP,
```

```
C               DEGREES CELSIUS.                                        C
C                                                                       C
C   ZZ          MAXIMUM OF TVPFAC(2) AND ZERO.  USED AS AN ENVIRONMENTAL C
C               INDEX, DECIMAL FRACTION, 0 TO 1.                        C
C                                                                       C
C                                                                       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
      DBGFLG=.FALSE.
      IF (DEBUG3 .GT. 1E-5) Q=MOD(((TIME-TSTART)/DT),DEBUG3)
      IF((DEBUG3 .GT. 1.E-5) .AND. (Q .LT. 1.E-5)) DBGFLG=.TRUE.
      IF(DBGFLG) WRITE(3,10) PMJDAT
   10 FORMAT('0****************     PMJDAT =', I4)
      PMJDAY=PMJDAT
C
C   RESET SOME THINGS ONCE A YEAR
      IF(PMJDAT .GE. PMDT) GO TO 30
      DO 20 J=1,PMFGPS
      CUMPSN(J)=0.0
      CUMRSP(J)=0.0
      CUMTRP(J)=0.0
      XVPLNT(J,5) = XVPLNT(J,5) + XVPLNT(J,4)
   20 XVPLNT(J,4) = 0.0
   30 CONTINUE
C
C
C
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C   THIS IS THE MAIN LOOP IN THIS SUBROUTINE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DO 200 J=1,PMFGPS
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
C   FIND WETTEST SOIL LAYER
      TVPSI=-3500.
      N=0
      DO 70 K=1,PMLYRS
      IF (CVRDST(J,K)-.1) 70,40,40
   40 IF ((XHSOLT(K+1) .LE. 0.) .AND. ((CWPSI(K)-50.) .GT. TVPSI))
     1 GO TO 50
      IF ((XHSOLT(K+1) .GT. 0.) .AND. (CWPSI(K) .GT. TVPSI)) GO TO 60
      GO TO 70
   50 N=K
      TVPSI=CWPSI(K)-50.
      GO TO 70
   60 N=K
      TVPSI=CWPSI(K)
   70 CONTINUE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C   SOIL WATER POTENTIAL AND AIR TEMP FACTOR
      TVPFAC(2)=F1(FTAVE(PMDT, 15), DATA1(1,1,J), NPTS1(J))
      TVTCOR=20.-TVPFAC(2)
      X=ZAIRT+.35*(ZTMAX-ZAIRT)
      TVPFAC(2) = F3 (X+TVTCOR, TVPSI, DATA51(1,1,J), NR51, NC51)
C   ZAIRR IS SIMPLY A VARIABLE USED TO HANG ON TO THE VALUE OF X
      ZAIRR=X
C
C
C   ZZ IS USED IN MOISTURE-DEGREE DAY SECTION AS WILL AS IN SUBROUTINES
C   VGROW AND VDETH
      ZZ = AMAX1(TVPFAC(2), 0.0)
C
C   NITROGEN FACTOR
      TVPFAC(3)=F1(XNMN,DATA3(1,1,J),NPTS3(J))
C
C   WATER VAPOR DIFFERENCE FACTOR
C   WATER VAPOR DENSITY DIFFERENCE BETWEEN LEAF AND AIR, MG/L
      TVPFAC(5)=(FWVP(ZAIRR)*216.6/(ZAIRR+273.))*(1.-ZRH)
      TVPFAC(5) = F3 (TVPFAC(5), TVPSI, DATA52(1,1,J), NR52, NC52)
C
      X = AMIN1( TVPFAC(2), TVPFAC(3), TVPFAC(5))
C
C   FRACTION OF POSSIBLE SUNLIGHT FACTOR
      TVPFAC(7)=F1(ZSUN, DATA9, NPTS9(1))
      X=X*TVPFAC(7)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C   GET PHENOLOGY INFORMATION
      CALL VPHEN( J, PMDT, PMFGPS, PMJDAT, TVPP, ZZ, DBGFLG)
C
```

```
C  PHENOPHASE OF THIS FUNCTIONAL GROUP
      NNN=TVPP(J)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C  CVPHS(J) WILL BECOME NET PRIMARY PRODUCTION (NOT QUITE THE SAME AS
C  NET PHOTOSYNTHESIS - DIFFERENT BY A FACTOR OF .74 TO BE PRECISE -
C  THE FACTOR THAT CONVERTS FROM PHOTOSYNTHATE TO STRUCTURE) OF
C  FUNCTIONAL GROUP J DURING DAYLIGHT
C  HOURS OF PMDT
      CVPHS(J)=0.
      DO 80 K=1,5
   80 CVPHS(J)=CVPHS(J)+.74*X*XVPLNT(J,K)*PVPRAT(J,K,NNN)*ZPHPD*
     1 PMDT
C
      IF(DBGFLG)
     1 WRITE(3,90) J,                  N, TVPSI, TVTCOR, ZAIRR,
     2(TVPFAC(K), K=2,7), CVPHS(J)
   90 FORMAT(' J=', I1,                                  ' N=',
     1 I2, ' TVPSI=', F5.1, ' TVTCOR=', F6.2, ' ZAIRR=', F5.2, ' TVPFAC=
     2', 6F5.3, ' CVPHS=', F7.2)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
C  RESPIRATION SECTION
C
C
C  RESPIRATION OF PHOTOSYNTHESISING PARTS DURING DARK HOURS OF PMDT
      X = ZAIRT - .35*(ZAIRT-ZTMIN)
      TRRFAC = F3(X, TVPSI, DATA53(1,1,J), NR53, NC53)
      IF(TRRFAC .LT. 0.) TRRFAC=0.0
C
      T=0.0
      DO 100 K=1,5
  100 T=T + .74*XVPLNT(J,K)*TRRFAC*PVRRAT(J,K,NNN)*(24.-ZPHPD)*PMDT
C
C  ROOT RESPIRATION FOR ALL HOURS OF PMDT
      TVSOLT=0.
      TVPS2=0
      DO 110 K=2,PMLYRS+1
      TVPS2=TVPS2+TVPSI*CVRDST(J,K-1)
  110 TVSOLT=TVSOLT+XHSOLT(K)*CVRDST(J,K-1)
C
      TVRFAC = F3 (TVSOLT, TVPS2, DATA53(1,1,J), NR53, NC53)
      IF (TVRFAC .LT. 0.) TVRFAC=0.
C
      TVRSPR = .74*XVPLNT(J,6)*TVRFAC*PVRRAT(J,6,NNN)*24.*PMDT
      TVRSPR=TVRSPR+T
C
      CUMPSN(J)=CUMPSN(J)+CVPHS(J)
      CUMRSP(J)=CUMRSP(J)+TVRSPR
C
C
      IF(DBGFLG)
     1   WRITE(3,120)  X, TRRFAC, TVPS2, TVSOLT, TVRFAC, T, TVRSPR,
     2      (XVPLNT(J,K), K=1,6)
  120 FORMAT(' X', F6.2, ' TRRFAC', F5.3, ' TVPS2', F6.2, ' TVSOLT',
     1F6.2, 'TVRFAC', F5.3, 'T', F7.2, ' TVRSPR', F7.2,
     2   ' XVPLNT', 6F7.1)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C  DETERMINE TRANSPIRATION
C
      CALL VTRANS
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C  PARTITION NET PHOTOSYNTHATE
C
      CALL VGROW
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C  ANIMAL REMOVAL SECTION
C
      DO 130 K=1,6
      IF((CAAR(J,K) + CADEST(J,K)) .LE. XVPLNT(J,K))  GO TO 130
      D=CAAR(J,K)+CADEST(J,K)
      CAAR(J,K)=CAAR(J,K)*XVPLNT(J,K)/D
      CADEST(J,K)=CADEST(J,K)*XVPLNT(J,K)/D
  130 CONTINUE
C
      DO 140 K=1,2
```

```
      XVLITR(2,2)=XVLITR(2,2)+CADEST(J,K)
  140 XVPLNT(J,K)=XVPLNT(J,K)-CADEST(J,K)
C
      XVLITR(2,3)=XVLITR(2,3)+CADEST(J,3)
      XVPLNT(J,3)=XVPLNT(J,3)-CADEST(J,3)
C
      DO 150 K=4,5
      XVLITR(2,4)=XVLITR(2,4)+CADEST(J,K)
  150 XVPLNT(J,K)=XVPLNT(J,K)-CADEST(J,K)
C
      DO 160 K=1,PMLYRS
      M=K+2
  160 XVLITR(M,4)=XVLITR(M,4)+CVRDST(J,K)* CADEST(J,6)
C
      XVPLNT(J,6)=XVPLNT(J,6)-CADEST(J,6)
C
      DO 170 K=1,6
      XVPLNT(J,K)=XVPLNT(J,K)-CAAR(J,K)
      IF(XVPLNT(J,K) .LT. 1.E-4)  XVPLNT(J,K)=1.E-4
  170 CONTINUE
C
C
C
      IF(DBGFLG)
     1 WRITE(3,180) (XVPLNT(J,K),K=1,6)
  180 FORMAT(' XVPLNT=', 6F7.1)
  190 FORMAT(' ', 5(3F6.1, F6.0, 2X))
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      CALL VDETH
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
  200 CONTINUE
C
C  END LOOP THROUGH FUNCTIONAL GROUPS
C
C***********************************************************************
C***********************************************************************
C***********************************************************************
C
C
C
C
      IF(DBGFLG)
     1 WRITE(3,210) (CUMPSN(K), K=1,PMFGPS), (CUMRSP(K), K=1,PMFGPS)
     2 (CUMTRP(K), K=1,PMFGPS)
  210 FORMAT(' CUMPSN, CUMRSP, CUMTRP', 9F9.1)
C
      IF(DBGFLG)
     1 WRITE(3,190) ((XVLITR(K,KK),KK=1,4),K=1,PMN+1)
C
C
C  MISCELLANEOUS TOTALS FOR GRAPHING PURPOSES
C
      XVTOTL=0.
      DO 230 J=1,PMFGPS
      XVFG(J,1)=XVPLNT(J,1)
      XVFG(J,2)=XVPLNT(J,2)+XVPLNT(J,3)
      XVFG(J,3)=XVPLNT(J,4)
      XVFG(J,4)=XVPLNT(J,5)
      XVFG(J,5)=XVFG(J,1)+XVFG(J,2)+XVFG(J,3)+XVFG(J,4)
  230 XVTOTL=XVTOTL+XVFG(J,5)
C
C  CALCULATE COVER
      X=PVCOV*(XVTOTL**.66667)
      CVVCOV=1.-(1.-CVVCOV)*(1.-X)
C
C
      RETURN
C
C
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
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CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
C
C
C
      ENTRY VINIT
C
C
C  INITIALIZATION SECTION
C  VARIABLES PECULIAR TO VEG ARE READ IN AND WRITTEN OUT, AND SIMILAR
```

```
C  INITIALIZATION SECTIONS IN SUBROUTINES SUPPORTING VEG ARE CALLED.
C
C
       COMMON TIME,TSTART,TEND,DT,DTPR,DTPL,
     1CAAR(6,8),CADEST(6,8),CADETH,CAUWST,CODL(12,4),CHD(10),CHDX(10),
     2CHDXX(10),CNFIX,CNSDF,CNSDS,CNSOMF,CNSOMS,CNSUP,CVDFTH(12,4),
     3CVLTFR(11,4),CVPHEN(6,8),CVPHS(6),CVRDST(6,10),CVTSPR(6,8),CVVCOV,
     4CWINF,CWPSI(10),PMDT,PMDTPL,PMDTPR,PMFGPS,PMJDAT,PMN,PMNCOH,PMNSP,
     5PWK(10),XAA(4),XAAVWT(4,8),XAAWT(4),XAFTS(4),XAFWT(4),XANUMB(4,8),
     6XASA(4),XASAWT(4),XAYNG(4),XAYWT(4),XHSOLT(10),XNMN,XNSOMF,XNSOMS,
     7XVFG(6,5),XVLITR(12,4),XVPLNT(6,8),XVTOTL,XWTHTA(10),XWSTND,ZAIRT,
     8ZEVAP,ZESUM,ZPHPD,ZRAIN,ZRSUM,ZRH,ZRINT,ZRISUM,ZSUN,ZTMAX,ZTMIN,
     9ZWIND
C
       COMMON/DB/DEBUG1,DEBUG2,DEBUG3
C
       COMMON/PCOM/CUMTRP,DRGFLG,J,NNN,PMLYRS,TVRSPR,TVTCOR,ZAIRR,ZZ
C
       DIMENSION CUMPSN(6), CUMRSP(6), CUMTRP(6), PVPRAT(6,5,5),
     1 PVRRAT(6,6,5), RCHECK(20), TVPFAC(7), TVPP(6)
C
       DIMENSION DATA1(5,2,6),NPTS1(6),DATA2(27,3,6),NPTS2(6),
     1 DATA3(4,2,6),NPTS3(6),DATA4(4,2,6),NPTS4(6),
     2 DATA9(2,2), NPTS9(1),
     3 DATA51(8,6,3), DATA52(3,4,3), DATA53(8,6,3)
C
       INTEGER PMLYRS, PMJDAY, PMJDAT, TVPP
C
       LOGICAL DRGFLG
C
C
  240 FORMAT(20A4)
  250 FORMAT(' ', 20A4)
  260 FORMAT(' ')
  270 FORMAT(10F12.6)
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
       WRITE(6,260)
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
       READ(5,/) DEBUG3
       WRITE(6,/) DEBUG3
       WRITE(6,260)
C
       PMLYRS=PMN-2.
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
       READ(5,/)((CVRDST(J,K),K=1,PMLYRS),J=1,PMFGPS)
       WRITE(6,/)((CVRDST(J,K),K=1,PMLYRS),J=1,PMFGPS)
       WRITE(6,260)
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
       READ(5,/)((XVLITR(J,K),K=1,4),J=1,PMLYRS+2)
       WRITE(6,/)((XVLITR(J,K),K=1,4),J=1,PMLYRS+2)
       WRITE(6,260)
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
       READ(5,/)((XVPLNT(J,K),K=1,6),J=1,PMFGPS)
       WRITE(6,/)((XVPLNT(J,K),K=1,6),J=1,PMFGPS)
       WRITE(6,260)
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
       READ(5,/)      (((PVPRAT(J,K,L), L=1,5), K=1,5), J=1,PMFGPS)
       WRITE(6,270)   (((PVPRAT(J,K,L), L=1,5), K=1,5), J=1,PMFGPS)
       WRITE(6,260)
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
       READ(5,/)      (((PVRRAT(J,K,L), L=1,5), K=1,6), J=1,PMFGPS)
       WRITE(6,270)   (((PVRRAT(J,K,L), L=1,5), K=1,6), J=1,PMFGPS)
       WRITE(6,260)
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
        READ(5,/)(NPTS1(J),J=1,PMFGPS)
       WRITE(6,/)(NPTS1(J),J=1,PMFGPS)
       WRITE(6,260)
C
       READ(5,240) RCHECK
       WRITE(6,250) RCHECK
        READ(5,/)(((DATA1(J,K,L),J=1,5),K=1,2),L=1,PMFGPS)
       WRITE(6,/)(((DATA1(J,K,L),J=1,5),K=1,2),L=1,PMFGPS)
       WRITE(6,260)
C
```

```
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/) NR51, NC51
      WRITE(6,/) NR51, NC51
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/) DATA51
      WRITE(6,/) DATA51
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/)(NPTS3(J),J=1,PMFGPS)
      WRITE(6,/)(NPTS3(J),J=1,PMFGPS)
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/)(((DATA3(J,K,L),J=1,4),K=1,2),L=1,PMFGPS)
      WRITE(6,/)(((DATA3(J,K,L),J=1,4),K=1,2),L=1,PMFGPS)
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/)(NPTS4(J),J=1,PMFGPS)
      WRITE(6,/)(NPTS4(J),J=1,PMFGPS)
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/)(((DATA4(J,K,L),J=1,4),K=1,2),L=1,PMFGPS)
      WRITE(6,/)(((DATA4(J,K,L),J=1,4),K=1,2),L=1,PMFGPS)
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/) NR52, NC52
      WRITE(6,/) NR52, NC52
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/) DATA52
      WRITE(6,/) DATA52
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/) NPTS9(1)
      WRITE(6,/) NPTS9(1)
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/)((DATA9(J,K),J=1,2),K=1,2)
      WRITE(6,/)((DATA9(J,K),J=1,2),K=1,2)
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/) NR53, NC53
      WRITE(6,/) NR53, NC53
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
       READ(5,/) DATA53
      WRITE(6,/) DATA53
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
      READ(5,/) PVCOV
      WRITE(6,/) PVCOV
      WRITE(6,260)
C
      READ(5,240) RCHECK
      WRITE(6,250) RCHECK
C
      WRITE(6,260)
      WRITE(6,260)
      WRITE(6,260)
      WRITE(6,260)
C
C
C  CALL INITIALIZATION SECTIONS OF VPHEN, VGROW, VDETH, VTRANS
C
      CALL VPINIT( J, PMDT, PMFGPS, PMJDAT, TVPP,ZZ)
```

```
      CALL VGINIT
      CALL VDINIT
      CALL VTINIT
C
C
      RETURN
      END
```

Subroutine VPHEN

```
      SUBROUTINE VPHEN( J, PMDT, PMFGPS, PMJDAT, TVPP, ZZ, DBGFLG)
C
C  WRITTEN BY    PAUL W. LOMMEN
C                DESERT BIOME - ECOLOGY CENTER  UMC 52
C                UTAH STATE UNIVERSITY
C                LOGAN, UTAH 84322
C
C     AUGUST 1976
C
C
C  VPHEN SIMULATES PHENOPHASE (PH.PH.) OF FUNCTIONAL GROUP(FG).  THERE
C  ARE 5 POSSIBILITIES WHICH NORMALLY ARE, 1. WINTER DORMANCY,
C  2. LEAFING OUT, 3. VEGETATIVE GROWTH, 4. REPRODUCTIVE GROWTH,
C  5. POST REPRODUCTIVE GROWTH.   A FG IS ASSUMED TO BE ENTIRELY
C  IN ONE PH.PH.    EACH YEAR OF SUMULATION EACH FG GOES THROUGH ALL
C  PH.PH.'S ONCE AND ONLY ONCE.
C
C
C  ABBREVIATIONS USED ARE FG FOR PERENNIAL PLANT FUNCTIONAL GROUP AND
C  PH.PH. FOR PHENOPHASE.
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C     VARIABLE DICTIONARY FOR VPHEN
C
C
C  FLAG        LOGICAL VARIABLE WHICH EQUALS .TRUE. IF PH. PH. OF CURRENT
C              FG IS TO BE INCREASED BY 1 THIS TIME STEP.
C
C  FTAVE (PMDT,10)    FUNCTION WHICH CALCULATES AVERAGE AIR TEMPERATURE
C              FOR PREVIOUS 10 DAYS GIVEN THAT THE TIME STEP LENGTH HAS
C              BEEN OF LENGTH PMDT.
C
C  NNN         CURRENT PH.PH. OF CURRENT FG. IT IS EQUAL TO, AND MUCH
C              EASIER TO PUNCH THAN TVPP(J).
C
C  PMJDAT      CURRENT JULIAN DAY
C
C  PVENV (J,NNN)    ENVIRONMENTAL INDEX PARAMETER FOR FG J IN PH.PH.
C              NNN. THE LAST OF THREE TESTS WHICH MUST BE MET FOR
C              ENVIRONMENTAL COMBINATION FACTOR TO SWITCH PH.PH. IS ZZ.GE
C              PVENN (J,NNN).
C
C  PVJD (J,NNN)     JULIAN DAY FACTOR FOR FG J WHEN ITS PH.PH. IS NNN.
C              THAT IS, IF PMJDAT IS GREATER THAN OR EQUAL TO
C              PVJD(J,NNN),THEN NNN IS INCREMENTED TO THE NEXT PH.PH.
C
C  PVMDD (J,NNN)    MOISTURE- DEGREE DAY PARAMETER FOR FG J IN PH.PH.
C              NNN. THE FIRST OF THREE TESTS WHICH MUST BE MET IF
C              ENVIRONMENTAL COMBINATION FACTOR IS TO SWITCH PH.PH. IS
C              TVMDD(J) .GE. PVMDD(J,NNN).
C
C
C  PVTMIN(J,NNN)    MINIMUM TEMPERATURE FACTOR FOR FG J WHEN ITS PH.PH.
C              IS NNN. IF GREATER THAN OR EQUAL TO TV, SWITCH TO NEXT
C              PH.PH.
C
C  PVTV(J,NNN)    TEMPERATURE PARAMETER FOR FG J IN PH.PH. NNN. THE
C              SECOND OF THREE TESTS WHICH MUST BE MET IF ENVIRONMENTAL
C              COMBINATION FACTOR IS TO SWITCH PH.PH. IS TV .GE.
C              PVTL(J,NNN).
C
C  TV          AVERAGE AIR TEMPERATURE DURING PREVIOUS TEN DAYS, DEGREES
C              CELSIUS
C
C  TVA(J)      PHENOPHASE OF FG J AT BEGINNING OF EXECUTION OF
C              SUBROUTINE VPHEN
C
C  TVDAY(J)    AN INTEGER VARIABLE, USED FOR DEBUGGING, WHICH STORES
C              THE JULIAN DATE OF THE PH.PH. SWITCH OF FG J.
C
C  TVMDD(J)    RUNNING SUM FROM JANUARY 1 OF MOISTURE DEGREE DAYS FOR FG
C              J, DAY.
```

```
C
C  TVPP(J)     CURRENT PH.PH. OF FG J
C
C  TVSW(J)     AN INTEGER VARIABLE, USED FOR DEBUGGING PURPOSES, WHICH
C              INDICATES THE TEST WHICH CAUSED THE PH.PH. OF FG J TO
C              CHANGE.  EQUALS 4 IF JULIAN DAY FACTOR CAUSED SWITCH, 2
C              IF MINIMUM TEMPERATURE, 1 IF ENVIRONMENTAL COMBINATION.
C              IF MORE THAN ONE FACTOR COULD HAVE CAUSED SWITCH, TVSW(J)
C              IS SUM OF INDIVIDUAL INDICES. E.G. IF ALL FACTORS SAY
C              SWITCH THEN TVSW(J)=7.
C
C  ZZ          ENVIRONMENTAL INDEX GENERATED IN VEG. VARIES BETWEEN 0
C              (UNFAVORABLE FOR GROWTH) AND 1 (OPTIMAL FOR GROWTH).
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C
C
C  TVMDD IS MOISTURE DEGREE DAYS AND SIMPLY IS THE CUMULATIVE SUM FROM
C  JANUARY 1 EACH YEAR OF TVPFAC(2)*PMDT. ( FOR POSITIVE TVPFAC(2))
C  (REMEMBER, TVPFAC(2) IS THE PHOTOSYNTHESIS SCALING FACTOR FOR AIR TEM
C  PERATURE AND SOIL WATER POTENTIAL.)
C
C  RESET TVMDD AT JANUARY 1 EACH YEAR
      IF(PMJDAT .GE. PMDT) GO TO 20
      DO 10 I=1,PMFGPS
   10 TVMDD(I) = 0.0
   20 CONTINUE
C
C  KEEP RUNNING SUM OF MOISTURE=DEGREE DAYS
      TVMDD(J) = TVMDD(J) + ZZ*PMDT
C
C  DON'T ALLOW SWITCH INTO PH. PH. 2 LATE IN YEAR
      IF((TVA(J) .GT. 1) .OR. ((TVA(J) .EQ. 1) .AND. (PMJDAT .LE. 175)))
     1    GO TO 30
      NNN = 1
      TVPP(J) = 1
      GO TO 100
C
   30 CONTINUE
      TV = FTAVE( PMDT, 10)
      NNN=TVA(J)
C
C
C  VARIABLES FLAG, TVSW AND TVDAY ARE HELPFUL IN DEBUGGING IN TELLING
C  ON WHAT DAY AND FOR WHAT REASON THE PHENOPHASE WAS SWITCHED.
      FLAG=.FALSE.
      I=TVSW(J)
      TVSW(J)=0
      IF(PMJDAT .GE. PVJD(J,NNN)) GO TO 40
      GO TO 50
   40 FLAG=.TRUE.
      TVSW(J)=4
      TVDAY(J)=PMJDAT
C
   50 IF(TV .LT. PVTMIN(J,NNN)) GO TO 60
      GO TO 70
   60 FLAG=.TRUE.
      TVSW(J)=TVSW(J)+2
      TVDAY(J)=PMJDAT
C
   70 IF ((TVMDD(J) .GE. PVMDD(J,NNN)) .AND. (TV .GE. PVTL(J,NNN))
     1    .AND. (ZZ .GE. PVENV(J,NNN))) GO TO 80
      GO TO 90
   80 FLAG=.TRUE.
      TVSW(J)=TVSW(J)+1
      TVDAY(J)=PMJDAT
   90 CONTINUE
C
      IF(FLAG) NNN=NNN+1
      IF(.NOT. FLAG) TVSW(J)=I
      IF(NNN .GT. 5)  NNN=1
      TVA(J)=NNN
      TVPP(J)=NNN
  100 CONTINUE
C
C
      IF(DBGFLG)WRITE(3,110)TV,NNN,TVMDD(J),ZZ,PVMDD(J,NNN),PVTL(J,NNN)
     1 , TVSW(J), TVDAY(J)
  110 FORMAT(' PPPPPPPPPP   TV=', F8.2, ' NNN=', I2, ' TVMDD(J)=', F8.2,
     1  ' ZZ=', F8.3, ' PVMDD(J,NNN)=', F8.3, ' PVTL(J,NNN)=', F8.3,
     2 ' TVSW=', I1, ' TVDAY=', I3)
      RETURN
C
C
      ENTRY VPINIT( J, PMDT, PMFGPS, PMJDAT, TVPP, ZZ)
C
      DIMENSION TVA(6), PVJD(6,5)
      DIMENSION TVSW(6), TVDAY(6)
      DIMENSION TVMDD(6), TVPP(6), RCHECK(20)
      DIMENSION PVENV(6,5), PVMDD(6,5), PVTL(6,5), PVTMIN(6,5)
```

```
C
      LOGICAL DBGFLG, FLAG
C
      INTEGER TVSW
      INTEGER TVPP, TVA, PMDT, PMFGPS, PVJD, PMJDAT
C
C  READ INITIAL DATA FOR PHENOLOGY SUBROUTINE
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
      READ(5,/) ((PVENV(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,/)  ((PVENV(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,150)
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
      READ(5,/)  ((PVMDD(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,/) ((PVMDD(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,150)
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
      READ(5,/)    ((PVTL(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,/)   ((PVTL(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,150)
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
      READ(5,/)    ((PVTMIN(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,/)   ((PVTMIN(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,150)
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
      READ(5,/)     (TVMDD(J), J=1,PMFGPS)
      WRITE(6,/)    (TVMDD(J), J=1,PMFGPS)
      WRITE(6,150)
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
      READ(5,/)     (TVPP(J), J=1,PMFGPS)
      WRITE(6,/)    (TVPP(J), J=1,PMFGPS)
      WRITE(6,150)
C  TVA HOLDS VALUE OF TVPP, PHENOPHASE, AS OF BEGINNING OF CALL TO VPHEN
C  I HAVE TO DO SOMETHING CUTE LIKE THIS OR ELSE TVPP GETS ZEROED FIRST
C  TIME VPHEN IS CALLED.
      DO 120 I=1, PMFGPS
  120 TVA(I)=TVPP(I)
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
      READ(5,/)    ((PVJD(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,/)   ((PVJD(J,K), K=1,5), J=1,PMFGPS)
      WRITE(6,150)
C
      READ(5,130) RCHECK
      WRITE(6,140) RCHECK
      WRITE(6,150)
      WRITE(6,150)
C
  130 FORMAT(20A4)
  140 FORMAT(' ', 20A4)
  150 FORMAT(' ')
C
C
      RETURN
      END
```

Subroutine VGROW

```
      SUBROUTINE VGROW
C
C     AUGUST 1976
C  WRITTEN BY    PAUL W. LOMMEN
C                DESERT BIOME - ECOLOGY CENTER  UMC 52
C                LOGAN, UTAH 84322
C                UTAH STATE UNIVERSITY
C
C
```

```
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C        VARIABLE DICTIONARY FOR VGROW
C
C   ABBREVIATIONS COMMONLY USED ARE FG FOR FUNCTIONAL GROUP AND PHPH
C   FOR PHENOPHASE.
C
C   A(I)          FRACTION OF TVNPS PLANT PART I WILL GET, DIMENSIONLES
C
C   CVPHS(J)      NET PHOTOSYNTHATE PRODUCTION OF FG J DURING DAYLIGHT PART
C                 OF TIMESTEP, KG HA-1
C
C   J             INDEX OF CURRENT FG
C
C   NNN           PH.PH. OF FG J
C
C   PMDT          TIMESTEP LENGTH, DAY.
C
C   PVHT(FG,PP,PHPH)    HALF TIMES REQUIRED FOR PLANT TO BUILD UP PART
C                 (LEAVES, FRUITS, FLOWERS) UNDER OPTIMUM CONDITIONS
C
C   PVLR(FG,I)          FACTORS LEAVES AND REPRODUCTIVE PARTS ARE MULTIPLIED
C                 BY IN ALLOCATING NEGATIVE TVNET.
C
C   PVPF(FG,PP,PHPH,1&2)  INTERCEPT AND SLOPE OF LINE WITH ENV. INDEX AS
C                 INDEPENDENT VARIABLE TO DETERMINE PROPORTIONALITY FACTOR
C                 FOR ALLOCATION OF REMAINDER OF TVNET.  DEPENDS ON FG, PP,
C                 AND PHPH.
C
C   PVPROP(FG,PP,PHPH,1&2)     INTERCEPT AND SLOPE OF LINE WITH
C                 ENVIRONMENTAL INDEX AS INDEPENDENT VARIABLE TO
C                 DETERMINE ALLOCATION PROP. FOR 1ST 5 PLANT PARTS
C
C   PVRSA(FG,K,L)   ROOT SHOOT ALLOCATION RATIO AS IT DEPENDS ON PHENOPH.
C
C   RS            ROOT - SHOOT ALLOCATION RATIO FOR PRESENT F.G.
C                 THIS TIME STEP, DIMENSIONLESS.
C
C   RSTOT         ROOT - SHOOT RATIO OF TOTALS ALLOCATED THIS YEAR
C                 TO ALL F.G.'S.
C
C   RTOT          TOTAL ALLOCATED TO ROOTS OF ALL F.G.'S SINCE
C                 JANUARY 1, KG HA-1.
C
C   SSUM          TOTAL ALLOCATED ABOVE GROUND THIS TIME STEP
C                 TO PRESENT F.G. KG HA-1.
C
C   STOT          TOTAL ALLOCATED TO SHOOTS OF ALL F.G.'S SINCE
C                 JANUARY 1, KG HA-1.
C
C   T(1)          ALLOCATION TO PART 1 THIS TIME STEP OF PRESENT F.G.
C                 IN ORDER TO BRING IT UP TOWARD NOMINAL LEVEL, KG HA-1
C
C   TSUM          SUM OVER I OF T(I), KG HA-1.
C
C   TVNET         REMAINING PHOTOSYNTHATE TO ALLOCATE, KG HA-1
C
C   TVNP          NET PHOTOSYNTHATE FOR PRESENT F.G., TIME STEP, KG HA-1
C
C   TVNPR         ROOTS' SHARE OF TVNP AFTER REMOVAL OF T(I)'S, KG HA-1
C
C   TVNPS         SHOOTS' SHARE OF TVNP AFTER REMOVAL OF T(I)'S, KG HA-1
C
C   TVRSPR        RESPIRATION OF FG J, KG HA-1
C
C   X             TEMPORARY VARIABLE
C
C   XP            NOMINAL PROPORTION OF TOTAL BIOMASS OF FG J FOR PP I.
C
C   XVPLNT(J,I)   BIOMASS OF PP I OF FG J,  KG HA-1.
C
C   Y             AMOUNT OF BIOMASS INCREMENT NEEDED BY PP I IN ORDER FOR IT
C                 TO REACH NOMINAL PROPORTION XP.
C
C   Z             LARGEST PORTION OF Y WHICH WILL BE ALLOWED TO BE ALLOCATED
C
C   ZZ            ENVIRONMENTAL INDEX WHICH VARIES FROM 0 (UNFAVORABLE FOR
C                 GROWTH) TO 1 (FAVORABLE FOR GROWTH).
C
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C
C
C   CALCULATE NET PHOTOSYNTHATE
      TVNET=CVPHS(J) - TVRSPR
      TVNP=TVNET
C
C   CALCULATE INCREASE ABOVE GROUND PARTS THINK THEY NEED
C
```

```
C  X IS ABOUT TO BECOME TOTAL BIOMASS
      X=0.0
      DO 10 I=1,6
   10 X = X + XVPLNT(J,I)
C
C
      DO 20 I=1,5
C  FIND PROPORTION CURRENT PLANT PART IS AIMING FOR
      XP = PVPROP(J,I,NNN,1) + ZZ * PVPROP(J,I,NNN,2)
      Y = X * XP - XVPLNT(J,I)
C  Y IS AMOUNT CURRENT PLANT PART WOULD LIKE TO ADD
C  DON'T PENALIZE PART IF SOMEHOW IT GREW TOO MUCH
      IF(Y .LT. 0.0) Y=0.0
C  NOW FIND LARGEST PORTION OF Y WE CAN ALLOW IT TO CHANGE (IF ZZ = 1)
      Z = 1. - EXP(-.693147*PMDT / PVHT(J,I,NNN))
C  THE BIOMASS INCREMENT WE WILL ACTUALLY ALLOCATE IS T(I)
      T(I) = Y * Z * ZZ
C
      XVPLNT(J,I) = XVPLNT(J,I) + T(I)
      IF(XVPLNT(J,I) .LE. 0.0) XVPLNT(J,I) = 1.E-4
      TVNET = TVNET - T(I)
   20 CONTINUE
C
C
C  DIVIDE UP TNVET REMAINING
C  CALCULATE ROOT-SHOOT ALLOCATION RATIO
      X = PVRSA(J,1,NNN) + ZZ * PVRSA(J,2,NNN)
C  ROOTS' SHARE
      TVNPR = (X/(X+1.)) * TVNET
      XVPLNT(J,6) = XVPLNT(J,6) + TVNPR
C
C  REMAINDER GOES TO SHOOT PARTS IN PROPORTION TO PRODUCT OF THEIR
C  BIOMASS AND PROPORTIONALITY FACTOR WHICH IS DEPENDENT ON
C  PHENOPHASE AND ENVIRONMENTAL INDEX.
      X=0.0
      DO 30 I=1,5
      A(I)=(PVPF(J,I,NNN,1) + ZZ*PVPF(J,I,NNN,2)) * XVPLNT(J,I)
   30 X = X + A(I)
      IF(X .LT. .001) X=.001
C
      X=1./X
      DO 40 I=1,5
   40 A(I)=A(I)*X
C  A(I) IS FRACTION OF SHOOT TVNET THAT PART I WILL GET IF TVNET .GT. 0.
C
C  IF TVNET IS NEGATIVE TAKE A DIFFERENT AMOUNT FROM LEAVES AND
C  REPRODUCTIVE ORGANS (LESS, PRESUMABLY)
      IF(TVNET .GE. 0.0) GO TO 80
C  ADJUST A ARRAY
      DO 50 I=1,3
   50 A(I)=A(I)*PVLR(J,I)
      X=0.0
      DO 60 I=1,5
   60 X = X + A(I)
      IF(X .LE. 1.E-4)  X=1.E-4
      DO 70 I=1,5
   70 A(I)=A(I)/X
C
   80 CONTINUE
C  NOW MOVE THE MATERIAL
      TVNPS = TVNET - TVNPR
      DO 90 I=1,5
      XVPLNT(J,I) = XVPLNT(J,I) + TVNPS * A(I)
   90 IF(XVPLNT(J,I) .LE. 0.0) XVPLNT(J,I)=1.E-4
C
C
      TSUM=0.0
      DO 100 I=1,4
  100 TSUM=TSUM + T(I)
      SSUM=TSUM + TVNPS
C
      IF(ABS(SSUM) .LT. 1.) RS=99.99
      IF(ABS(SSUM) .LT. 1.) GO TO 110
      RS = TVNPR/SSUM
  110 CONTINUE
C
      IF(PMJDAT .GE. PMDT) GO TO 120
      RTOT=0.0
      STOT=0.0
  120 CONTINUE
C
      RTOT=RTOT+TVNPR
      STOT=STOT+SSUM
      IF(ABS(STOT) .GT. 1.) GO TO 130
      RSTOT=99.99
      GO TO 140
  130 CONTINUE
      RSTOT=RTOT/STOT
  140 CONTINUE
C
```

```
      IF(DBGFLG)
     1  WRITE(3,150) TVNP, TVNPR, TVNPS, T, A, SSUM, RS, RTOT, STOT,
     2    RSTOT
  150 FORMAT(' GGG NP,NPR,NPS', 3F6.1, 'T', F6.1,2F4.1,2F6.1,'A',5F4.3,
     1    'SSUM', F6.1, ' RS', F6.2, 'R, S, RS', 2F6.0, F6.3)
C
      RETURN
C
C
C
C
C
      ENTRY VGINIT
C
      COMMON TIME,TSTART,TEND,DT,DTPR,DTPL,
     1CAAR(6,8),CADEST(6,8),CADETH,CAUWST,CDDL(12,4),CHD(10),CHDX(10),
     2CHDXX(10),CNFIX,CNSDF,CNSDS,CNSOMF,CNSOMS,CNSUP,CVDETH(12,4),
     3CVLTFR(11,4),CVPHEN(6,8),CVPHS(6),CVRDST(6,10),CVTSPR(6,8),CVVCOV,
     4CWINF,CWPSI(10),PMDT,PMDTPL,PMDTPR,PMFGPS,PMJDAT,PMN,PMNCOH,PMNSP,
     5PWK(10),XAA(4),XAAVWT(4,8),XAAWT(4),XAFTS(4),XAFWT(4),XANUMB(4,8),
     6XASA(4),XASAWT(4),XAYNG(4),XAYWT(4),XHSOLT(10),XNMN,XNSOMF,XNSOMS,
     7XVFG(6,5),XVLITR(12,4),XVPLNT(6,8),XVTOTL,XWTHTA(10),XWSTND,ZAIRT,
     8ZEVAP,ZESUM,ZPHPD,ZRAIN,ZRSUM,ZRH,ZRINT,ZRISUM,ZSUN,ZTMAX,ZTMIN,
     9ZWIND
C
      COMMON/PCOM/CUMTRP,DBGFLG,J,NNN,PMLYRS,TVRSPR,TVTCOR,ZAIRR,ZZ
C
      INTEGER PMFGPS, PMDT, TVPP
C
      LOGICAL DBGFLG
C
      DIMENSION A(5), PVHT(6,5,5), PVPROP(6,5,5,2), PVRSA(6,2,5),
     1    PVLR(6,3), RCHECK(20), TVPP(6)
C
      DIMENSION PVPF(6,5,5,2)
      DIMENSION CUMTRP(6), T(5)
C
C
C  READ INITIAL DATA
C
      READ(5,160) RCHECK
      WRITE(6,170) RCHECK
      WRITE(6,180)
C
      READ(5,160) RCHECK
      WRITE(6,170) RCHECK
      READ(5,/)     (((PVHT(J,K,L), L=1,5), K=1,5), J=1,PMFGPS)
      WRITE(6,190)  (((PVHT(J,K,L), L=1,5), K=1,5), J=1,PMFGPS)
      WRITE(6,180)
C
      READ(5,160) RCHECK
      WRITE(6,170) RCHECK
      READ(5,/)     ((PVLR(J,K),K=1,3), J=1,PMFGPS)
      WRITE(6,/)    ((PVLR(J,K),K=1,3), J=1,PMFGPS)
      WRITE(6,180)
C
      READ(5,160) RCHECK
      WRITE(6,170) RCHECK
      READ(5,/)     ((((PVPROP(J,K,L,M),M=1,2),L=1,5),K=1,5),J=1,PMFGPS)
      WRITE(6,190)  ((((PVPROP(J,K,L,M),M=1,2),L=1,5),K=1,5),J=1,PMFGPS)
      WRITE(6,180)
C
      READ(5,160) RCHECK
      WRITE(6,170) RCHECK
      READ(5,/)     ((((PVPF(J,K,L,M),M=1,2),L=1,5),K=1,5),J=1,PMFGPS)
      WRITE(6,190)  ((((PVPF(J,K,L,M),M=1,2),L=1,5),K=1,5),J=1,PMFGPS)
      WRITE(6,180)
C
      READ(5,160) RCHECK
      WRITE(6,170) RCHECK
      READ(5,/)     (((PVRSA(J,K,L), L=1,5), K=1,2), J=1,PMFGPS)
      WRITE(6,/)    (((PVRSA(J,K,L), L=1,5), K=1,2), J=1,PMFGPS)
      WRITE(6,180)
C
      READ(5,160) RCHECK
      WRITE(6,170) RCHECK
      WRITE(6,180)
C
C
  160 FORMAT(20A4)
  170 FORMAT(' ', 20A4)
  180 FORMAT(' ')
  190 FORMAT(10F12.5)
C
C
      RETURN
      END
```

Subroutine VTRANS

```
      SUBROUTINE VTRANS
C
C   APRIL 1976         PAUL LOMMEN
C
C
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C         VARIABLE DICTIONARY FOR VTRANS
C
C   CVTSPR(J,L)TRANSPIRATION OF FG J FROM SOIL LAYER L, KG WATER HA-1
C
C   DATA        ARRAY STORING PAIRS OF DATA POINTS FOR RELATIONSHIP
C               BETWEEN FACTOR F AND DIFFERENCE BETWEEN ACTUAL AND
C               OPTIMUM TEMPERATURE.
C
C   F           FACTOR TO "CORRECT" P/T RATIO FOR DIFFERENCE BETWEEN
C               ACTUAL AND OPTIMUM TEMPERATURE.
C
C   F1          FUNCTION WHICH INTERPOLATES OVER SINGLE INDEPENDENT
C               VARIABLE.
C
C   FWVP(T)     FUNCTION WHICH DETERMINES SATURATED WATER VAPOR PRESSURE
C               AT TEMPERATURE (IN DEGREES CELSIUS) T, MB.
C
C   NPTS        NUMBER OF PAIRS OF DATA POINTS IN ARRAY DATA.
C
C   PVPT(1&2)   PARAMETERS OF STRAIGHT LINE GIVING RELATIONSHIP BETWEEN
C               P/T AND WATER PRESSURE VAPOR DIFFERENCE BETWEEN LEAF
C               AND AIR.
C
C   TVPT        P/T=RATIO OF PHOTOSYNTHESIS (KG CO2 HA-1) TO
C               TRANSPIRATION (KG WATER HA-1)
C
C   TVTCOR      DIFFERENCE BETWEEN 20 DEGREES CELSIUS AND CURRENT OPTIMUM
C               TEMPERATURE FOR FG J. CALCULATED IN VEG, DEGREES CELSIUS.
C
C   TVWVD       WATER VAPOR PRESSURE DIFFERENCE BETWEEN LEAF AND AIR, MB.
C
C   X           DIFFERENCE BETWEEN ACTUAL AND OPTIMUM TEMPERATURE DEGREES
C               CELSIUS.
C
C   ZAIRR       AVERAGE TIME STEP AIR TEMPERATURE, DETERMINED IN PSWG,
C               DEGREES CELSIUS.
C
C   ZRH         AVERAGE TIME STEP RELATIVE HUMIDITY, DETERMINED IN
C               PSWG, DECIMAL FRACTION BETWEEN 0 AND 1.
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C
C
C   DETERMINE WATER VAPOR PRESSURE DIFFERENCE BETWEEN LEAF AND AIR (MB)
      TVWVD = FWVP(ZAIRR) * (1.-ZRH)
C
C   FIND VALUE OF P/T IF TEMPERATURE AT OPTIMUM
      TVPT = PVPT(1) + PVPT(2) * TVWVD
C
C   ADJUST THIS FOR TEMPERATURE BY MULTIPLYING BY A FACTOR F
C   X IS THE DIFFERENCE BETWEEN ACTUAL AND OPTIMUM TEMPERATURES.
      X = ZAIRR - (20. - TVTCOR)
C
      F = F1(X, DATA, NPTS)
      TVPT = TVPT * F
C
C   CHECK IF VALUE REASONABLE
      IF((TVPT .GT. .030) .OR. (TVPT .LT. .0005)) TVPT = .009
C
C   SUBROUTINE WATER DETERMINES FROM WHICH LAYER TRANSPIRATION
C   IS REMOVED SO PUT ENTIRE DEMAND IN CVTSPR AS THOUGH IT'S FROM LAYER 1
C
C   CALCULATE TRANSPIRATION - DON'T ALLOW NEGATIVE VALUES
C   THE .74 APPEARS HERE TO CONVERT CVPHS BACK TO WEIGHT OF CO2 TAKEN UP
      CVTSPR(J,1) = ABS(CVPHS(J) / (.74 * TVPT) )
C
C   ACCUMULATE IT
      CUMTRP(J) = CUMTRP(J) + CVTSPR(J,1)
C
C
      RETURN
C
C
      ENTRY VTINIT
C
      COMMON TIME, TSTART, TEND, DT, DTPR, DTPL,
     1CAAR(6,8),CADEST(6,8),CADETH,CAUWST,CODL(12,4),CHD(10),CHDX(10),
     2CHDXX(10),CNFIX,CNSDF,CNSDS,CNSOMF,CNSOMS,CNSUP,CVDETH(12,4),
     3CVLTFR(11,4),CVPHEN(6,8),CVPHS(6),CVRDST(6,10),CVTSPR(6,8),CVVCOV,
     4CWINF,CWPSI(10),PMDT,PMDTPL,PMDTPR,PMFGPS,PMJDAT,PMN,PMNCOH,PMNSP,
```

```
     5PWK(10),XAA(4),XAAVWT(4,8),XAAWT(4),XAFTS(4),XAFWT(4),XANUMB(4,8),
     6XASA(4),XASAWT(4),XAYNG(4),XAYWT(4),XHSOLT(10),XNMN,XNSOMF,XNSOMS,
     7XVFG(6,5),XVLITR(12,4),XVPLNT(6,8),XVTOTL,XWTHTA(10),XWSTND,ZAIRT,
     8ZEVAP,ZESUM,ZPHPD,ZRAIN,ZRSUM,ZRH,ZRINT,ZRISUM,ZSUN,ZTMAX,ZTMIN,
     9ZWIND
C
      DIMENSION DATA(10), RCHECK(20), PVPT(2), CUMTRP(6)
C
      COMMON/PCOM/CUMTRP,DBGFLG,J,NNN,PMLYRS,TVRSPR,TVTCOR,ZAIRR,ZZ
C
  850 FORMAT(20A4)
  851 FORMAT(' ', 20A4)
  852 FORMAT(' ')
C
      READ(5,850) RCHECK
      WRITE(6,851) RCHECK
C
      READ(5,850) RCHECK
      WRITE(6,851) RCHECK
      READ(5,/) NPTS
      WRITE(6,/) NPTS
      WRITE(6,852)
C
      READ(5,850) RCHECK
      WRITE(6,851) RCHECK
      READ(5,/) DATA
      WRITE(6,/) DATA
      WRITE(6,852)
C
      READ(5,850) RCHECK
      WRITE(6,851) RCHECK
      READ(5,/)PVPT
      WRITE(6,/) PVPT
      WRITE(6,852)
C
      READ(5,850) RCHECK
      WRITE(6,851) RCHECK
      WRITE(6,852)
      WRITE(6,852)
C
C
      RETURN
      END
```

Subroutine VDETH

```
      SUBROUTINE VDETH
C
C  WRITTEN BY    PAUL W. LOMMEN
C                DESERT BIOME - ECOLOGY CENTER  UMC 52
C                UTAH STATE UNIVERSITY
C                LOGAN, UTAH 84322
C
C     AUGUST 1976
C
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C        VARIABLE DICTIONARY FOR VDETH
C
C  CVRDST (J,L)  ROOT DISTRIBUTION IN LAYER L OF FG J. THE SUM OVER
C             L FOR EACH J EQUALS 1.
C
C  PMDT        LENGTH  OF TIME STEP, DAY.
C
C  PVDTH(FG, PP, PHPH, ENV)  INSTANTANEOUS DEATH RATES AS FUNCTIONS OF
C                            FUNCTIONAL GROUP, PLANT PART, PHENOLOGICAL
C                            INDEX, ENVIRONMENTAL INDEX, DAY-1.
C
C  PVRSB(FG,PHPH,1+2)        PARAMETERS OF STRAIGHT LINE DEPENDENT ON
C                            ENVIRONMENTAL INDEX GIVING ROOT - SHOOT
C                            BIOMASS RATIO WHICH PLANT TRIES TO REACH BY
C                            FUNCTIONAL GROUP AND PHENOPHASE.
C
C  TVDETH (K) NOMINAL INSTANTANEOUS DEATH RATE OF PLANT PART K, DAY-1
C
C  TVDTH(K)    AMOUNT OF PP K DYING THIS TIME STEP, KG HA-1.
C
C  X           TOTAL SHOOT BIOMASS OF FG J, KG HA-1.
C
C  XVLITR(L,M)    LITTER AMOUNT IN LOCATION L (STANDING, SOIL SURFACE
C             UP TO 8 SOIL LAYERS) OF TYPE M (FECES, SOFT, HARD, WOODY),
C             KG HA-1.
```

```
C
C  XVPLNT(J,K)  DRY WEIGHT BIOMASS OF PP K OF FG J, KG HA-1.
C
C  Y            CURRENT ROOT-SHOOT RATIO OF FG J.
C
C  Z            NOMINAL ROOT-SHOOT RATIO.
C
C  ZZ           ENVIRONMENTAL INDEX CALCULATED IN VEG.  EQUALS 0 IF
C               CONDITIONS  UNFAVORABLE FOR GROWTH, EQUALS 1 FOR
C               IDEAL CONDITIONS.
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C
C  NOMINAL DEATH RATES
      DO 10 K=1,6
      TVDETH(K) = PVDTH(J,K,NNN,1) - ZZ*PVDTH(J,K,NNN,2)
   10 IF(TVDETH(K) .LT. 0.0)  TVDETH(K)=0.0
C
C
C  IF ROOT - SHOOT RATIO TOO HIGH OR TOO LOW FIDDLE WITH DEATH RATE
C
C  FIRST, ROOT-SHOOT RATIO
      X=0.0
      DO 20 K=1,5
   20 X = X + XVPLNT(J,K)
      IF(X .LT. 5.) X=5.
      Y=XVPLNT(J,6)/X
C
C  CALL THE NOMINAL ROOT-SHOOT RATIO Z
      Z = PVRSB(J,NNN,1) - ZZ * PVRSB(J,NNN,2)
C  HERE IS THE ADJUSTED DEATH RATE
      TVDETH(6)=TVDETH(6) * Y / Z
C
C  TVDETH IS INSTANTANEOUS DEATH RATE(UNITS OF DAY-1).
C  NOW DETERMINE TVDTH(K), AMOUNT OF PART K DYING THIS TIME STEP.
      DO 30 K=1,6
   30 TVDTH(K)=XVPLNT(J,K) * (1. - EXP(-TVDETH(K)*PMDT))
C
C  DO THE XVLITR AND XVPLNT BOOKKEEPING
C
C  ABOVE GROUND LITTER
      XVLITR(1,2) = XVLITR(1,2) + TVDTH(1) + TVDTH(2)
      XVLITR(1,3) = XVLITR(1,3) + TVDTH(3)
      XVLITR(1,4) = XVLITR(1,4) + TVDTH(4) + TVDTH(5)
C
C  BELOW GROUND LITTER
      DO 40 K=1,PMLYRS
      M=K+2
   40 XVLITR(M,4)=XVLITR(M,4) + TVDTH(6)*CVRDST(J,K)
C
C  SHOOTS AND ROOTS
      DO 50 K=1,6
   50 XVPLNT(J,K) = XVPLNT(J,K) - TVDTH(K)
C
C
      IF(DBGFLG) WRITE(3,60) TVDETH, TVDTH
   60 FORMAT(' DDDDDD  TVDETH ', 6F6.4, '    TVDTH ', 6F8.2)
C
C
      RETURN
C
C
      ENTRY VDINIT
C
C
      COMMON TIME,TSTART,TEND,DT,DTPR,DTPL,
     1CAAR(6,8),CADEST(6,8),CADETH,CAUWST,CDDL(12,4),CHD(10),CHDX(10),
     2CHDXX(10),CNFIX,CNSDF,CNSDS,CNSOMF,CNSOMS,CNSUP,CVDETH(12,4),
     3CVLTFR(11,4),CVPHEN(6,8),CVPHS(6),CVRDST(6,10),CVTSPR(6,8),CVVCOV,
     4CWINF,CWPSI(10),PMDT,PMDTPL,PMDTPR,PMFGPS,PMJDAT,PMN,PMNCOH,PMNSP,
     5PWK(10),XAA(4),XAAVWT(4,8),XAAWT(4),XAFTS(4),XAFWT(4),XANUMB(4,8),
     6XASA(4),XASAWT(4),XAYNG(4),XAYWT(4),XHSOLT(10),XNMN,XNSOMF,XNSOMS,
     7XVFG(6,5),XVLITR(12,4),XVPLNT(6,8),XVTOTL,XWTHTA(10),XWSTND,ZAIRT,
     8ZEVAP,ZESUM,ZPHPD,ZRAIN,ZRSUM,ZRH,ZRINT,ZRISUM,ZSUN,ZTMAX,ZTMIN,
     9ZWIND
C
C
      COMMON/PCOM/CUMTRP,DBGFLG,J,NNN,PMLYRS,TVRSPR,TVTCOR,ZAIRR,ZZ
C
      INTEGER PMLYRS
      LOGICAL DBGFLG
C
      DIMENSION PVDTH(6,6,5,2), PVRSB(6,5,2), TVDETH(6), TVDTH(6)
      DIMENSION RCHECK(20)
      DIMENSION CUMTRP(6)
C
C  READ INITIAL VALUES
C
      READ(5,70) RCHECK
      WRITE(6,80) RCHECK
```

```
      WRITE(6,90)
C
      READ(5,70) RCHECK
      WRITE(6,80) RCHECK
      READ(5,/)    ((((PVDTH(J,K,L,M),M=1,2),L=1,5),K=1,6),J=1,PMFGPS)
      WRITE(6,100)((((PVDTH(J,K,L,M),M=1,2),L=1,5),K=1,6),J=1,PMFGPS)
      WRITE(6,90)
C
      READ(5,70) RCHECK
      WRITE(6,80) RCHECK
      READ(5,/)     (((PVRSB(J,K,L), L=1,2), K=1,5), J=1,PMFGPS)
      WRITE(6,100) (((PVRSB(J,K,L), L=1,2), K=1,5), J=1,PMFGPS)
      WRITE(6,90)
C
      READ(5,70) RCHECK
      WRITE(6,80) RCHECK
      WRITE(6,90)
C
   70 FORMAT(20A4)
   80 FORMAT(' ', 20A4)
   90 FORMAT(' ')
  100 FORMAT(10F12.6)
C
      RETURN
C
      END
```

Function FWVP

```
      FUNCTION FWVP(T)
C
C
C     4-7-76       PAUL LOMMEN
C  GIVEN TEMPERATURE IN DEGREES CELSIUS THIS FUNCTION RETURNS SATURATION
C  WATER VAPOR PRESSURE IN MB.
C  "TRUE" VALUES WERE TAKEN FROM P 352 SMITHSONIAN MET. TABLES.
C  AT -5 C, EQUATION GIVES A VALUE 1.4% HIGH.   BETWEEN 0C AND 45C
C  EQUATION VARIES BETWEEN EXTREMES OF .29% LOW AND .33% HIGH.
C  AT 50C IT IS .71% LOW.
C
C
      FWVP=EXP(1.81337 + 0.0714*T - 0.00023*T*T)
C
C
      RETURN
      END
```

LITERATURE CITED

French, N., and R. H. Sauer. 1974. Phenological studies and modeling in grasslands. Section 4.3 *in* H. Leith, ed. Phenology and seasonality modeling, Vol 8. Ecological Studies, Analysis and Synthesis. Springer-Verlag, New York.

Heasley, J. E. 1976. Programming phase of water response ecosystem model: III. Animal submodel. US/IBP Desert Biome Res. Memo. 76-38. Utah State Univ., Logan. 9 pp.

List, R. J. 1949. Smithsonian meteorological tables, 6th ed. Smithsonian Misc. Collection Vol. 114. Smithsonian Inst. Press, Washington, D.C. 527 pp.

Lommen, P. W. 1976. Programming phase of water response ecosystem model: I. Introduction and support programs. US/IBP Desert Biome Res. Memo. 76-36. Utah State Univ., Logan. 9 pp.

Lommen, P. W., and K. A. Marshall. 1976. Programming phase of water response ecosystem model: II. Abiotic submodels. US/IBP Desert Biome Res. Memo. 76-37. Utah State Univ., Logan. 81 pp.

Schultze, E. D., O. L. Lange, and A. Olsen. 1974. An approach for a photosynthesis model of desert plants. US/IBP Desert Biome Res. Memo. 74-57. Utah State Univ., Logan. 17 pp.

B. NITROGEN SUBMODEL

P. W. Lommen

GENERAL DESCRIPTION OF THE NITROGEN SUBMODEL

The nitrogen submodel, called N, simulates simply, but realistically, the flows of nitrogen in a desert ecosystem. Early in the development of the Water Response Ecosystem Model, it was decided that plant growth would depend on soil mineral nitrogen level. Thus, a nitrogen submodel was needed, but it was to be as simple as possible since the overall model objective called for simulation of above-ground phytomass amounts rather than soil nitrogen dynamics or amounts. Figure B-1 is a box-and-arrow diagram of the nitrogen submodel.

Nitrogen flows simulated in N include decomposition, mineralization, fixation, nitrogen in precipitation, denitrification and uptake. Many of the ideas in N came from the work of Gist et al. (in press), Reuss and Innis (in press) and from helpful discussions with J. Skujins, A. Wallace, E. M. Romney, R. B. Hunter and C. S. Gist.

The input of nitrogen from precipitation is proportional to precipitation amount (Gist et al. in press).

The rate of input of nitrogen from fixation is proportional to factors for soil surface temperature and for soil water potential near the surface. The proportionality factor is a constant which depends only on the site being simulated. Ideally, this factor might be proportional to the biomass of the fixers, but this would be beyond the requirements of the Water Response Ecosystem Model.

Volatilization of NH_3 is assumed negligible. Denitrification of mineral nitrogen is proportional to the amount of mineral nitrogen in the soil, and soil temperature and soil water potential factors at about 10-cm depth. As with fixation, the proportionality factor is a site-dependent constant.

Nitrogen in litter decomposed is divided between mineral nitrogen and soil organic matter pools by a scheme adapted from Reuss and Innis (in press). Decomposition is handled in a separate submodel (see Section C, below). For each type of litter (feces, soft, hard, woody), a constant fraction of nitrogen in decomposed litter goes to the mineral nitrogen

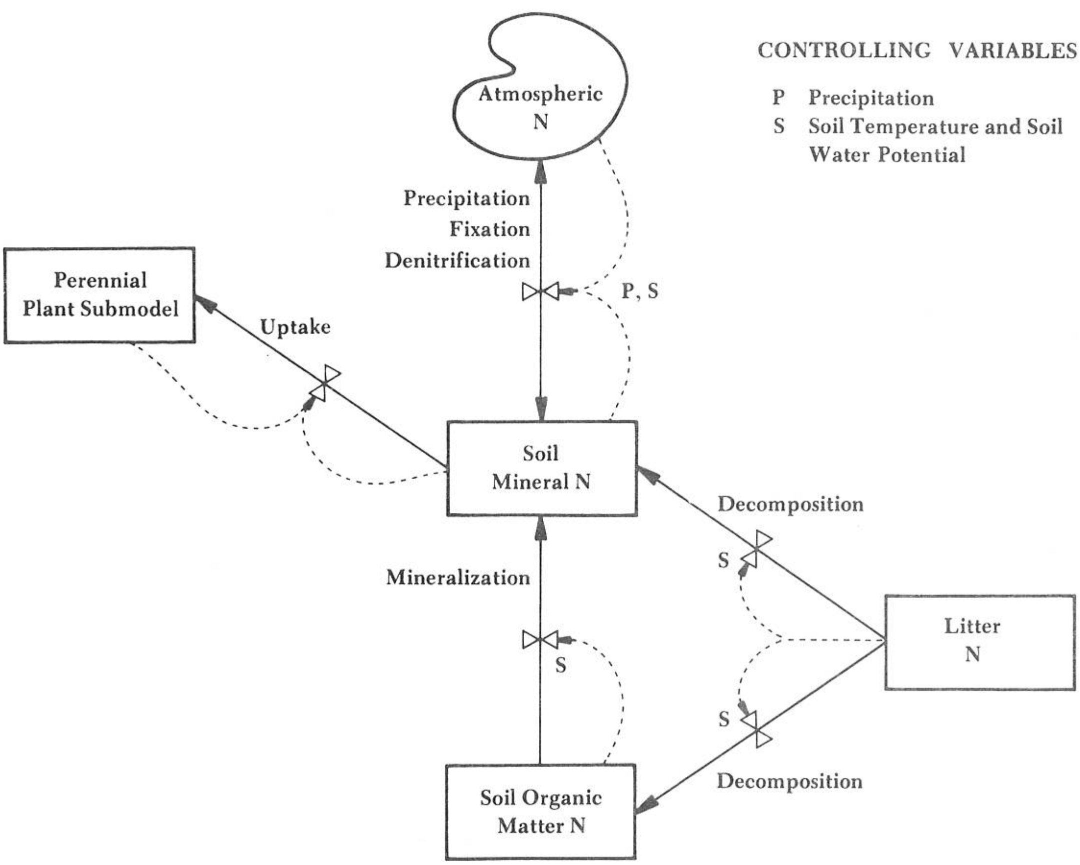

Figure B-1. Simplified box-and-arrow diagram for the nitrogen submodel.

pool. This fraction depends on an estimate of the carbon:nitrogen ratio in a given litter type; the higher the ratio, the smaller the fraction to the mineral nitrogen pool.

The mineralization flow from soil organic nitrogen to mineral nitrogen is proportional to the size of the soil organic nitrogen pool and to factors for soil temperature and soil water potential. Again, the proportionality factor is a site-dependent constant.

Finally, uptake is proportional to amount of photosynthesis. The proportionality factor equals the fraction of nitrogen in fresh plant material (~ 0.02), times a factor which accounts for respiration (which equals 0.152 and was determined during the course of several runs of the model).

PROGRAM DESCRIPTION OF N

Only the important segments of the code in the program listing are shown and described. Sequence numbers are shown to aid in reference to full code listing which follows the Program Description. All comment cards, specification statements and bookkeeping sections have been left out. Almost all initialization has also been deleted. Definitions of variable names may be found in Table B-1, which also appears at the beginning of the Program Listing.

```
      TNUP=0.0                                NNN 132
      DO10I=1,PMFGPS                          NNN 133
      IF(CVPHS(I).LT.0.0)GOTO10               NNN 134
      TNUP=TNUP+CVPHS(I)                      NNN 135
   10 CONTINUE                                NNN 136
```

TNUP first becomes the sum over perennial plant functional groups of positive photosynthesis amounts.

```
      TNUP=TNUP*PNFNP*0.152                   NNN 137
```

Here, TNUP becomes mineral nitrogen amount, in $kg \cdot ha^{-1}$, taken up by perennial plants this time-step. It is proportional to total photosynthesis and fraction of nitrogen in fresh plant material. The proportionality factor was determined in early runs of the model.

```
      TNPRCP=0.016*ZRAIN                      NNN 149
```

The amount of mineral nitrogen getting into the soil profile via precipitation is proportional to the precipitation this time-step.

Table B-1. Variable dictionary for N

CDDL(I,J)	LITTER DECOMPOSED THIS TIME STEP (IN DCMP) IN LOCATION I (STANDING, SURFACE, SOIL LAYERS) OF TYPE J (FECES, SOFT, HARD, WOODY), KG DRY WGT HA-1.
CNFIX	SUM FROM OCT 1 OF FIXED N, KG N HA-1
CNSDF	SUM FROM OCT 1 OF N FROMLITTER TO MINERAL N, KG N HA-1
CNSDS	SUM FROM OCT 1 OF N FROM LITTER TO SOM, KG N HA-1
CNSOMF	SUM FROM OCT 1 OF N LOST FROM DENITRIFICATION, KG N HA-1
CNSOMS	SUM FROM OCT 1 OF N FROM SOM TO MINERAL N, KG N HA-1
CNSUP	SUM FROM OCT. 1 OF UPTAKE BY PLANTS, KG N HA-1.
CVPHS(J)	PHOTOSYNTHESIS THIS TIME STEP OF FUNCTIONAL GROUP J (CALCULATED IN VEG), KG HA-1.
CWPSI(L)	SOIL WATER POTENTIAL OF SOIL LAYER L, COUNTING FROM TOP LAYER, BARS.
DBGFLG	IF=.TRUE. WRITE DEBUGGING INFORMATION THIS TIME STEP
DEBUG1	NUMBER OF TIME STEPS BETWEEN DEBUGGING OUTPUTS
F1	FUNCTION WHICH INTERPOLATES BETWEEN GIVEN DATA POINTS AND DETERMINES TEMPERATURE AND WATER POTENTIAL FACTORS. THE ARGUMENT OF F1 IS; X VALUE, ARRAY OF DATA POINTS, NO. PAIRS OF DATA POINTS. THE ARRAY OF DATA POINTS MUST BE READ IN IN FREE FORMAT AS FOLLOWS; X1,X2,X3,X4,Y1,Y2,Y3,Y4 IN ASCENDING ORDER OF X.
PMDT	LENGTH OF TIME STEP, DAYS.
PNDNIT	MAXIMUM DENITRIFICATION RATE, KG N LOSS HA-1 PER KG MINERAL N HA-1 DAY
PNFIX	MAXIMUM FIXATION RATE, KG N HA-1 DAY-1
PNFMN(4)	FRACTION OF DECOMPOSING LITTER N GOING TO MINERAL N COMPARTMENT, DIMENSIONLESS
PNFNL	FRACTION N IN LITTER BY TYPE, FECES, SORT, HARD, WOODY, DIMENSIONLESS.
PNFNP	FRACTION OF N IN FRESH PLANT MATERIAL, DIMENSIONLESS.
PNROT	RULE OF THUMB FRACTION FOR MINERALIZATION, FRACTION YR-1.
PNTT(4,2)	TEMPERATURE DEPENDENCE CURVE, Y IS DIMENSIONLESS, X IS IN DEG. C.
PNWW(4,2)	SOIL WATER POTENTIAL DEPENDENCE CURVE, Y IS DIMENSIONLESS, X IS IN BARS.
TNCCC(20)	ARRAY FOR READING IN COMMENTS.
TNDNIT	DENITRIFICATION LOSS DURING PMDT, KG N HA-1
TNFIX	TOTAL N FIXED DURING PMDT, KG N HA-1
TNLMN	FLOW DURING PMDT FROM LITTER TO MINERAL N,KG N HA-1
TNLSOM	FLOW DURING PMDT FROM LITTER TO SOM, KG N HA-1
TNPRCP	FLOW DURING PMDT FROM N DISSOLVED IN PRECIP, KG N HA-1
TNSMN	FLOW DURING PMDT FROM SOM TO MINERAL N, KG N HA-1
TNUP	PLANT UPTAKE DURING PMDT, KG N HA-1.
XHSOLT(I)	TEMPERATURE OF SOIL NODE I, COUNTING FROM SURFACE. (THE FIRST SOIL LAYER IS CENTERED ON THE 2ND NODE.) DEGREES CELSIUS.
XNMN	MINERAL NITROGEN (AVAILABLE TO PLANTS), KG N HA-1.
XNSOMS	SOIL ORGANIC MATTER N, KG N HA-1

```
      TNFIX=PNFIX*PMDT*F1(XHSOLT(1),PNTT,4)*F1(CWPSI(1),PNWW,4)
```

The amount of mineral nitrogen fixed by soil microbes this time-step is proportional to: maximum daily rate; length of time-step; soil temperature factor between 0 and 1 (based on soil surface temperature); soil moisture factor between 0 and 1 (based on water potential of top layer). (Water potential of the soil surface is not calculated by the WATER submodel.)

```
      TNDNIT=XNMN*PNDNIT*PMDT*F1(XHSOLT(2),PNTT,4)*F1(CWPSI(1),PNWW,4)
```

The loss of mineral nitrogen due to denitrification is proportional to: amount of mineral nitrogen; maximum daily rate; length of time-step; soil temperature factor between 0 and 1 (based on temperature of first soil layer); soil moisture factor between 0 and 1 (based on water potential of top layer).

```
      TNLMN=0.0
      TNLSOM=0.0
      DO30J=1,4
      R=0.0
      DO20I=2,PMN
   20 R=R+CDDL(I,J)
      TNLMN=TNLMN+R*PNFNL(J)*PNFMN(J)
      TNLSOM=TNLSOM+R*PNFNL(J)*(1.-PNFMN(J))
   30 CONTINUE
```

Determine TNLMN and TNLSOM, amounts of nitrogen in decomposed litter going to mineral nitrogen and soil organic matter compartments, respectively. For each litter type J (feces, soft, hard, woody) we sum over soil surface and below-ground layers to find total of that type litter decomposed. This total is then multiplied by the fraction of nitrogen in that type litter and by the fraction of that type litter going to the mineral compartment. The remainder goes to the soil organic matter compartment.

```
      TNSMN=XNSOMS*PNROT*PMDT*0.033*F1(XHSOLT(3),PNTT,4)*F1(CWPSI(2),
     1 PNWW,4)
```

The amount of soil organic matter nitrogen transferred to the mineral nitrogen compartment, TNSMN, is equal to: the amount of soil organic matter nitrogen, XNSOMS; times PNROT, a "rule of thumb" parameter (typically .005 to .02) for the approximate yearly fraction of soil organic matter decomposing; times the length of the time-step; times .033, which is to be thought of as 1 year's activity per 30 optimum days; times a soil temperature factor between 0 and 1; times a soil water potential factor between 0 and 1. The factors for soil temperature and water potential are both keyed to values in the second soil layer (typically about 10-cm depth) which we roughly estimate to be close to the center of this activity.

```
      XNSOMS=XNSOMS+TNLSOM-TNSMN
```

The soil organic matter nitrogen compartment is increased this time-step by a flow from the litter compartment and decreased by mineralization.

```
XNMN=XNMN+TNPRCP+TNFIX+TNLMN+TNSMN-TNDNIT-TNUP
```

NNN 225

The mineral nitrogen compartment is increased by precipitation, fixation and flows from litter and soil organic matter. It is decreased by denitrification and uptake.

```
ENTRY NINIT
```

NNN 282

This entry point is called once from MAIN and is for initialization purposes. The reading and writing of input comments and variables is handled the same way as for VEG (Section A, this Research Memorandum).

COMPLETE PROGRAM LISTING

Subroutine N

```
      SUBROUTINE N
C
C  WRITTEN BY    PAUL W. LOMMEN
C                DESERT BIOME - ECOLOGY CENTER  UMC 52
C                UTAH STATE UNIVERSITY
C                LOGAN, UTAH 84322
C
C     AUGUST 1976
C
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C                         VARIABLES FOR N
C
C
C  CDDL(I,J)   LITTER DECOMPOSED THIS TIME STEP (IN DCMP) IN
C              LOCATION I (STANDING, SURFACE, SOIL LAYERS) OF
C              TYPE J (FECES, SOFT, HARD, WOODY), KG DRY WGT
C              HA=1.
C
C  CNFIX       SUM FROM OCT 1 OF FIXED N, KG N HA=1
C
C  CNSDF       SUM FROM OCT 1 OF N FROMLITTER TO MINERAL N, KG N HA=1
C
C  CNSDS       SUM FROM OCT 1 OF N FROM LITTER TO SOM, KG N HA=1
C
C  CNSOMF      SUM FROM OCT 1 OF N LOST FROM DENITRIFICATION, KG N HA=1
C
C  CNSOMS      SUM FROM OCT 1 OF N FROM SOM TO MINERAL N, KG N HA=1
C
C  CNSUP       SUM FROM OCT. 1 OF UPTAKE BY PLANTS, KG N HA=1.
C
C  CVPHS(J)    PHOTOSYNTHESIS THIS TIME STEP OF FUNCTIONAL
C              GROUP J (CALCULATED IN VEG), KG HA=1.
C
C  CWPSI(L)    SOIL WATER POTENTIAL OF SOIL LAYER L, COUNTING
C              FROM TOP LAYER, BARS.
C
C  DBGFLG      IF=.TRUE. WRITE DEBUGGING INFORMATION THIS TIME STEP
C
C  DEBUG1           NUMBER OF TIME STEPS BETWEEN DEBUGGING OUTPUTS
C
C  F1          FUNCTION WHICH INTERPOLATES BETWEEN GIVEN DATA POINTS AND
C              DETERMINES TEMPERATURE AND WATER POTENTIAL FACTORS.   THE
C              ARGUMENT OF F1 IS; X VALUE, ARRAY OF DATA POINTS, NO.
C              PAIRS OF DATA POINTS.  THE ARRAY OF DATA POINTS MUST BE
C              READ IN IN FREE FORMAT AS FOLLOWS; X1,X2,X3,X4,Y1,Y2,Y3,Y4
C              IN ASCENDING ORDER OF X.
C
C  PMDT        LENGTH OF TIME STEP, DAYS.
C
C  PNDNIT      MAXIMUM DENITRIFICATION RATE, KG N LOSS HA=1 PER
C              KG MINERAL N HA=1 DAY
C
C  PNFIX       MAXIMUM FIXATION RATE, KG N HA=1 DAY=1
C
C  PNFMN(4)    FRACTION OF DECOMPOSING LITTER N GOING TO MINERAL N
C              COMPARTMENT, DIMENSIONLESS
C
C  PNFNL       FRACTION N IN LITTER BY TYPE, FECES, SORT, HARD, WOODY,
C              DIMENSIONLESS.
C
C  PNFNP       FRACTION OF N IN FRESH PLANT MATERIAL, DIMENSIONLESS.
C
C  PNROT       RULE OF THUMB FRACTION FOR MINERALIZATION, FRACTION  YR=1.
C
C  PNTT(4,2)   TEMPERATURE DEPENDENCE CURVE,  Y IS DIMENSIONLESS,
C              X IS IN DEG. C.
C
C  PNWW(4,2)   SOIL WATER POTENTIAL DEPENDENCE CURVE, Y IS DIMENSIONLESS,
C              X IS IN BARS.
C
C  TNCCC(20)   ARRAY FOR READING IN COMMENTS.
C
C  TNDNIT      DENITRIFICATION LOSS DURING PMDT, KG N HA=1
C
C  TNFIX       TOTAL N FIXED DURING PMDT, KG N HA=1
C
C  TNLMN       FLOW DURING PMDT FROM LITTER TO MINERAL N,KG N HA=1
C
C  TNLSOM      FLOW DURING PMDT FROM LITTER TO SOM, KG N HA=1
C
C  TNPRCP      FLOW DURING PMDT FROM N DISSOLVED IN PRECIP, KG N HA=1
C
C  TNSMN       FLOW DURING PMDT FROM SOM TO MINERAL N, KG N HA=1
```

```
C
C  TNUP         PLANT UPTAKE DURING PMDT, KG N HA-1.
C
C  XHSOLT(I)    TEMPERATURE OF SOIL NODE I, COUNTING FROM SURFACE.
C               (THE FIRST SOIL LAYER IS CENTERED ON THE 2ND
C               NODE.) DEGREES CELSIUS.
C
C  XNMN         MINERAL NITROGEN (AVAILABLE TO PLANTS), KG N HA-1.
C
C  XNSOMS       SOIL ORGANIC MATTER N, KG N HA-1
C
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C
C
C
      COMMON TIME,TSTART,TEND,DT,DTPR,DTPL,
     1CAAR(6,8),CADEST(6,8),CADETH,CAUWST,CDDL(12,4),CHD(10),CHDX(10),
     2CHDXX(10),CNFIX,CNSDF,CNSDS,CNSOMF,CNSOMS,CNSUP,CVDETH(12,4),
     3CVLTFR(11,4),CVPHEN(6,8),CVPHS(6),CVRDST(6,10),CVTSPR(6,8),CVVCOV,
     4CWINF,CWPSI(10),PMDT,PMDTPL,PMDTPR,PMFGPS,PMJDAT,PMN,PMNCOH,PMNSP,
     5PWK(10),XAA(4),XAAVWT(4,8),XAAWT(4),XAFTS(4),XAFWT(4),XANUMB(4,8),
     6XASA(4),XASAWT(4),XAYNG(4),XAYWT(4),XHSOLT(10),XNMN,XNSOMF,XNSOMS,
     7XVFG(6,5),XVLITR(12,4),XVPLNT(6,8),XVTOTL,XWTHTA(10),XWSTND,ZAIRT,
     8ZEVAP,ZESUM,ZPHPD,ZRAIN,ZRSUM,ZRH,ZRINT,ZRISUM,ZSUN,ZTMAX,ZTMIN,
     9ZWIND
C
      COMMON/DB/DEBUG1,DEBUG2,DEBUG3
C
      INTEGER PMFGPS,PMN
C
      DIMENSION PNFNL(4), PNFMN(4) , PNTT(4,2), PNWW(4,2), TNCCC(20)
C
      LOGICAL DBGFLG
C
C
CUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
C  UPTAKE SECTION
C
C  FOR REALISM, UPTAKE IS PROPORTIONAL TO PHOTOSYNTHESIS.  WE ALSO
C  KNOW N CONTENT OF FRESH PLANT MATERIAL, PNFNP.  FROM RUN OF
C  12-19-74 WE WANTED PNFNP=0.03.  BY FAILING TO CONSIDER RESPIRATION,
C  HOWEVER, AND MAKING UPTAKE = 0.03 X PHOTOSYNTHESIS, NEW GROWTH WAS
C  2430 KG HA-1 BUT UPTAKE 480 KG HA-1.  THE DESIRED UPTAKE WAS
C  0. 3 X 2430 = 73 KG N HA-1.  THUS TAKE PROPORTIONALITY BETWEEN
C  GROWTH AND UPTAKE TO BE = PNFNP X 73 / 480 = PNFNP X 0.152
C
      TNUP=0.0
      DO10I=1,PMFGPS
      IF(CVPHS(I).LT.0.0)GOTO10
      TNUP=TNUP+CVPHS(I)
   10 CONTINUE
      TNUP=TNUP*PNFNP*0.152
C
C  END UPTAKE SECTION
CUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
C
C
C
C
CAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
C  ATMOSPHERE SECTION
C
C  FROM PRECIP,  FACTOR OF 0.016 KG N HA-1 MM-1   FROM GIST, WEST,MCKEE
      TNPRCP=0.016*ZRAIN
C
C  FROM FIXATION
C  IDEALLY MIGHT MAKE THIS PROPORTIONAL TO BIOMASS OF FIXERS BUT I THINK
C  THAT'S BEYOND WATER RESPONSE MODEL REQUIREMENTS
      TNFIX=PNFIX*PMDT*F1(XHSOLT(1),PNTT,4)*F1(CWPSI(1),PNWW,4)
C
C  DENITRIFICATION LOSS
C  ASSUME VOLATILIZATION LOSS OF NH4 NEGLIGIBLE
      TNDNIT=XNMN*PNDNIT*PMDT*F1(XHSOLT(2),PNTT,4)*F1(CWPSI(1),PNWW,4)
C  SKUJINS SAID TODAY ABOUT 1/3 OF SURFACE LITTER N IS DENITRIFIED AND
C  1/10 OF ROOT N IS DENITRIFIED.  SO IF UPTAKE=LITTER FALL = LITTER
C  DECOMPOSITION = 100 KG N HA-1 YR-1 AND ROOT/SHOOT = 3 THEN 1/3X25  +
C  1/10 X 75 = 16 KG N HA-1 YR-1.
C
C  END ATMOSPHERE SECTION
CAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
C
C
C
C
CDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
C  DECOMPOSITION SECTION
C
C  LOCATIONS CONSIDERED - - SURFACE, BELOW GROUND
C  TYPES CONSIDERED = FECES, SOFT, HARD, WOODY
```

```
C
C  TURNOVER TIMES FOR FECES, SOFT, HARD, WOODY PRESUMABLY WILL BE A FEW
C  MONTHS, A FEW MONTHS, ABOUT A YEAR, SEVERAL YEARS, RESPECTIVELY.  BUT
C  THESE TURNOVER TIMES (OR DECOMPOSITION RATES) WILL BE READ IN IN DCMP
C  AND SO CAN BE READILY CHANGED.
C
C
      TNLMN=0.0
      TNLSOM=0.0
      DO30J=1,4
      R=0.0
      DO20I=2,PMN
   20 R=R+CDDL(I,J)
      TNLMN=TNLMN+R*PNFNL(J)*PNFMN(J)
      TNLSOM=TNLSOM+R*PNFNL(J)*(1.-PNFMN(J))
   30 CONTINUE
C  THIS DIVISION OF DECOMPOSED LITTER HAS BEEN DIVIDED BETWEEN MINERAL
C  N AND SOM BY A SCHEME ADAPTED FROM       A GRASSLAND NITROGEN FLOW
C  SIMULATION MODEL, 1975(PREPRINT) J.O.REUSS AND G.S.INNIS.
C
C  END DECOMPOSITION SECTION
CDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
C
C
C
C
CMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
C  MINERALIZATION SECTION
C
C  THE SOIL ORGANIC MATTER IS A VERY STABLE COMPARTMENT WITH A TURNOVER
C  TIME OF 50-100 YEARS.    RULE OF THUMB ESTIMATES FOR SOM TURNOVER
C  ARE USUALLY ABOUT 2% PER YEAR.   HERE, I MUST USE A SMALLER FIGURE
C  IN ORDER TO BALANCE THE OVERALL N BUDGET.
C  0.033=1/30 IS A FACTOR TO BE THOUGHT OF AS 1 YEAR PER 30 OPTIMUM DAYS
      TNSMN=XNSOMS*PNROT*PMDT*0.033*F1(XHSOLT(3),PNTT,4)*F1(CWPSI(2),
     1 PNWW,4)
C  END MINERALIZATION SECTION
CMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
C
C
C
C
CIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
C  INCREMENT SECTION
C
C  SOIL ORGANIC MATTER N
      XNSOMS=XNSOMS+TNLSOM-TNSMN
      IF(XNSOMS.LT.0.0)XNSOMS=0.0
C
C  MINERAL N
      XNMN=XNMN+TNPRCP+TNFIX+TNLMN+TNSMN-TNDNIT-TNUP
      IF(XNMN.LT.0.0)XNMN=0.0
C
C
C
C  END INCREMENT SECTION
CIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
C
C
C
C
CSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
C  SUMMING SECTION
C
      IF(PMJDAT.LT.270)GOTO40
      IF(ABS(PMJDAT-270).GE.PMDT)GOTO40
      CNFIX=0.0
      CNSDF=0.0
      CNSDS=0.0
      CNSOMS=0.0
      CNSUP=0.0
      CNSOMF=0.0
   40 CONTINUE
      CNFIX=CNFIX+TNFIX
      CNSDF=CNSDF+TNLMN
      CNSDS=CNSDS+TNLSOM
      CNSOMS=CNSOMS+TNSMN
      CNSUP=CNSUP+TNUP
      CNSOMF=CNSOMF+TNDNIT
C
C  END SUMMING SECTION
CSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
C
C
C
C
CDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
C  DEBUGGING SECTION
C
      DBGFLG=.FALSE.
```

```
      IF(DEBUG1 .LT. 1.E-5) GO TO 50
      IF(MOD(((TIME-TSTART)/PMDT), DEBUG1) .LT. 1.E-5) DBGFLG=.TRUE.
   50 CONTINUE
      IF(.NOT. DBGFLG)  GO TO 80
   60 WRITE(1,70)XNMN,XNSOMS,CNFIX, TNFIX,CNSDF,TNLMN,CNSDS,TNLSOM,
     1CNSOMS,TNSMN,CNSUP,TNUP,CNSOMF,TNDNIT
   70 FORMAT(' NNNN   ************', F7.1, F9.1, 12F6.1)
   80 CONTINUE
C
C  END DEBUGGING
CDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
C
C
      RETURN
C
CEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
CEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
      ENTRY NINIT
C
C
C  READ AND WRITE COMMENTS , INITIAL DATA AND PARAMETERS
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)XNMN
      WRITE(6,120)XNMN
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)XNSOMS
      WRITE(6,120)XNSOMS
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)PNFNP
      WRITE(6,120)PNFNP
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)PNFIX
      WRITE(6,120)PNFIX
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)PNDNIT
      WRITE(6,120)PNDNIT
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)PNFNL
      WRITE(6,120)PNFNL
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)PNROT
      WRITE(6,120)PNROT
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)PNTT
      WRITE(6,120)PNTT
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)PNWW
      WRITE(6,120)PNWW
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      READ(5,/)PNFMN
      WRITE(6,120)PNFMN
      WRITE(6,110)
C
      READ(5,90)TNCCC
      WRITE(6,100)TNCCC
      WRITE(6,110)
C
```

```
C
   90 FORMAT(20A4)
  100 FORMAT(' ',20A4)
  110 FORMAT(' ')
  120 FORMAT(' ',8F14.5)
C
C
C
      RETURN
      END
```

LITERATURE CITED

GIST, C. S., N. E. WEST, and M. MCKEE. A computer simulation model of nitrogen dynamics in a Great Basin Desert ecosystem. Chapter 13 *in* N. E. West and J. Skujins, eds. Nitrogen in desert ecosystems. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pa. (In press)

REUSS, J. O., and G. S. INNIS. A grassland nitrogen flow simulation model. Ecology. (In press)

C. DECOMPOSITION SUBMODEL DCMP

P. W. Lommen

GENERAL DESCRIPTION OF DCMP

DCMP calculates the amount of litter, in $kg \cdot ha^{-1}$, separated by location and type, which is decomposed each time-step. This information is used by the nitrogen submodel to determine some key nitrogen fluxes. Locations are standing, surface and up to eight soil layers; types are feces, soft, hard and woody.

Each time-step in DCMP, a fixed fraction of each of the various litter categories is shifted downward by a transfer matrix (standing to surface, surface to first soil layer, etc.). The processes doing these transfers might be wind, rodents, insects, etc., but remain unspecified.

Next, a fraction F is determined for each litter category. F is the decimal fraction of a category decomposed during the current time-step. F depends on litter type, temperature and water potential factors at its location, and length of time-step:

$$F = 1 - \exp[(R)(F_T)(F_W)(\Delta t)] \qquad \text{(C-1)}$$

where R is maximum instantaneous (not daily!) rate of decomposition of this type of litter (units are day^{-1}), F_T and F_W are temperature and water potential factors, respectively, whose values are between 0 and 1, and Δt is the length of the time-step in days. It should be noted that standing litter is not decomposed until it is transferred to the soil surface.

Each litter category is then multiplied by the appropriate value of F and the result stored in an amount-decomposed array for use by the nitrogen submodel. The litter category is then decreased by this amount.

PROGRAM DESCRIPTION

Only the important segments of the code in the program listing are shown and described. Sequence numbers are shown to aid in reference to full code listing which follows the Program Description. Comment cards, specification statements and bookkeeping sections have been left out. Definitions of variable names may be found in Table C-1, which also appears at the beginning of the Program Listing.

Table C-1. Variable dictionary for DCMP

```
CDDL(12,4) AMOUNT OF LITTER DECOMPOSED DURING PMDT BY LOCATION,
           AND CATEGORY, KG HA=1

CVLTFR(11,4)  LITTER TRANSFER ARRAY,    CVLTFR(I,J) IS FRACTION PER
              DAY OF LITTER OF TYPE J, LOCATION I TRANSFERRED BY
              WIND, RODENTS, ETC. TO TYPE J LOCATION I+1. DMNSNLESS.

DBGFLG     IF=.TRUE. WRITE DEBUGGING INFORMATION THIS TIME STEP

DEBUG1          NUMBER OF TIME STEPS BETWEEN DEBUGGING OUTPUTS

F1         FUNCTION WHICH INTERPOLATES BETWEEN GIVEN DATA POINTS AND
           DETERMINES TEMPERATURE AND WATER POTENTIAL FACTORS.   THE
           ARGUMENT OF F1 IS; X VALUE, ARRAY OF DATA POINTS, NO.
           PAIRS OF DATA POINTS.  THE ARRAY OF DATA POINTS MUST BE
           READ IN IN FREE FORMAT AS FOLLOWS; X1,X2,X3,X4,Y1,Y2,Y3,Y4
           IN ASCENDING ORDER OF X.

PDTT(4,2)  TEMPERATURE DEPENDENCE CURVE,  Y IS DIMENSIONLESS,
           X IS IN DEGREES C.

PDWW(4,2) SOIL WATER POTENTIAL DEPENDENCE CURVE,  Y IS DIMENSIONLESS,
           X IS IN BARS.

PDR(4)     OPTIMUM INSTANTANEOUS DECOMPOSITION RATE BY CATEGORY,DAY=1

TDCCC(20)  ARRAY USED TO READ IN COMMENTS

XVLITR(12,4)  AMOUNT OF LITTER BY LOCATION, CATEGORY, KG/HA
```

```
      DO 10 M=0,PMLYRS                                                  DCMP 068
      K=PMLYRS+2-M                                                      DCMP 069
      DO 10 L=1,4                                                       DCMP 070
      XVLITR(K,L)=XVLITR(K,L)+XVLITR(K-1,L)*(1.-(1.-CVLTFR(K-1,L))      DCMP 071
     1 **PMDT)                                                          DCMP 072
   10 XVLITR(K-1,L)=XVLITR(K-1,L)-XVLITR(K-1,L)*(1.-(1.-CVLTFR(K-1,L))  DCMP 073
     1 **PMDT)                                                          DCMP 074
```

Transfer litter downward using rates in CVLTFR, starting at the bottom layer. CVLTFR(K—1,L) is the fraction per day of type L litter moving downward from location K—1 to location K.

The fraction remaining is 1—CVLTFR(K—1,L). After PMDT days, the fraction remaining is $[1—CVLTFR(K—1,L)]^{PMDT}$. The fraction moved down to location K is 1— $[1—CVLTFR(K—1,L)]^{PMDT}$. Thus, an amount, XVLITR(K—1,L) * $\{1—[1—CVLTFR(K—1,L)]^{PMDT}\}$, is added to XVLITR(K,L) and subtracted from XVLITR (K—1,L).

```
      DO 30 I=2,PMN                                                     DCMP 081
```

Beginning of main DO loop which calculates decomposition.

```
      K=I-2                                                             DCMP 083
      IF(I.LE.2)K=1                                                     DCMP 084
      FF=F1(CWPSI(K),PDWW,4)*F1(XHSOLT(I-1),PDTT,4)*PMDT                DCMP 085
```

First time through the loop is for surface litter where we want surface temperature XHSOLT(1) and water potential of the first layer CWPSI(1) (which is as close as we can get to water potential at the surface) used in calculating decomposition rates.

Second time through the loop is for the first layer in the soil where we want temperature of the first layer [= temp. of second node = XHSOLT(2)] and water potential of the first layer again [CWPSI(1)]. Many processes have exponential rates of decay (radioactive decay of some elements, animal mortality functions, etc.). If the instantaneous rate of decomposition of S is R, then

$$(dS/dT) = — RS$$

and it follows that

$$S = S_o e^{—Rt}, \text{ where t is time}$$

In this submodel,

R = (max. instantaneous decomp. rate) x (water pot. factor) x (temp. factor) x time

= PDR(J) x F1 (WATER) x F1 (TEMP) x PMDT

= PDR(J) x FF (C-2)

PMDT is the length in days of a time-step (note that an instantaneous rate is not the same as a daily rate). Within each litter location, FF is the same for all four categories of litter. That is why FF is calculated before the next statement.

```
      DO30J=1,4
```

DCMP 086

Now go through litter categories (feces, soft, hard, woody) for the present layer.

```
      IF(XVLITR(I,J).LE.0.0)GOTO20
```

DCMP 087

If there is no litter in this category there can be none decomposed, so go to 20.

```
      F=1.-EXP(-FF*PDR(J))
```

DCMP 088

F is the fraction of this litter category decomposed in this time-step.

```
      CDDL(I,J)=XVLITR(I,J)*F
```

DCMP 094

CDDL (I,J) is the amount of litter decomposed in this time-step.

```
      XVLITR(I,J)=XVLITR(I,J)*(1.-F)
```

DCMP 095

Reduce XVLITR accordingly. Because exponential is used to determine F, F is always $\leqslant 1$.

```
   20 CDDL(I,J)=0.0
```

DCMP 097

Reach here only if there is no litter in this category to decompose.

```
   30 CONTINUE
```

DCMP 098

End of both DO loops.

```
      ENTRY DINIT
```

DCMP 122

DCMP initialization section. The reading and writing of input variables is handled the same way as in subroutine VEG.

COMPLETE PROGRAM LISTING

Subroutine DCMP

```
      SUBROUTINE DCMP
C
C  DECOMPOSITION SUBMODEL OF WATER RESPONSE MODEL      MARCH 1976
C
C  WRITTEN BY        PAUL W. LOMMEN
C                    UTAH STATE UNIVERSITY   UMC52
C                    LOGAN, UTAH 84322
C
C
C
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C                         VARIABLE LIST FOR DCMP
C
C
C  CDDL(12,4) AMOUNT OF LITTER DECOMPOSED DURING PMDT BY LOCATION,
C             AND CATEGORY, KG HA-1
C
C  CVLTFR(11,4)  LITTER TRANSFER ARRAY,    CVLTFR(I,J) IS FRACTION PER
C                DAY OF LITTER OF TYPE J, LOCATION I TRANSFERRED BY
C                WIND, RODENTS, ETC. TO TYPE J LOCATION I+1. DMNSNLESS.
C
C
C  DBGFLG     IF=.TRUE. WRITE DEBUGGING INFORMATION THIS TIME STEP
C
C  DEBUG1          NUMBER OF TIME STEPS BETWEEN DEBUGGING OUTPUTS
C
C  F1         FUNCTION WHICH INTERPOLATES BETWEEN GIVEN DATA POINTS AND
C             DETERMINES TEMPERATURE AND WATER POTENTIAL FACTORS.   THE
C             ARGUMENT OF F1 IS; X VALUE, ARRAY OF DATA POINTS, NO.
C             PAIRS OF DATA POINTS.  THE ARRAY OF DATA POINTS MUST BE
C             READ IN IN FREE FORMAT AS FOLLOWS; X1,X2,X3,X4,Y1,Y2,Y3,Y4
C             IN ASCENDING ORDER OF X.
C
C  PDTT(4,2)  TEMPERATURE DEPENDENCE CURVE,  Y IS DIMENSIONLESS,
C             X IS IN DEGREES C.
C
C  PDWW(4,2) SOIL WATER POTENTIAL DEPENDENCE CURVE,  Y IS DIMENSIONLESS,
C             X IS IN BARS.
C
C  PDR(4)     OPTIMUM INSTANTANEOUS DECOMPOSITION RATE BY CATEGORY,DAY-1
C
C  TDCCC(20)  ARRAY USED TO READ IN COMMENTS
C
C  XVLITR(12,4)  AMOUNT OF LITTER BY LOCATION, CATEGORY, KG/HA
CVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV
C
      COMMON TIME,TSTART,TEND,DT,DTPR,DTPL,
     1CAAR(6,8),CADEST(6,8),CADETH,CAUWST,CDDL(12,4),CHD(10),CHDX(10),
     2CHDXX(10),CNFIX,CNSDF,CNSDS,CNSOMF,CNSOMS,CNSUP,CVDETH(12,4),
     3CVLTFR(11,4),CVPHEN(6,8),CVPHS(6),CVRDST(6,10),CVTSPR(6,8),CVVCOV,
     4CWINF,CWPSI(10),PMDT,PMDTPL,PMDTPR,PMFGPS,PMJDAT,PMN,PMNCOH,PMNSP,
     5PWK(10),XAA(4),XAAVWT(4,8),XAAWT(4),XAFTS(4),XAFWT(4),XANUMB(4,8),
     6XASA(4),XASAWT(4),XAYNG(4),XAYWT(4),XHSOLT(10),XNMN,XNSOMF,XNSOMS,
     7XVFG(6,5),XVLITR(12,4),XVPLNT(6,8),XVTOTL,XWTHTA(10),XWSTND,ZAIRT,
     8ZEVAP,ZESUM,ZPHPD,ZRAIN,ZRSUM,ZRH,ZRINT,ZRISUM,ZSUN,ZTMAX,ZTMIN,
     9ZWIND
C
      COMMON/DB/DEBUG1,DEBUG2,DEBUG3
C
      DIMENSION PDR(4),PDTT(4,2), PDWW(4,2), TDCCC(20)
C
      INTEGER DEBUG1, PMN, PMLYRS
C
      LOGICAL DBGFLG
C
C  LITTER TRANSFER BY UNSPECIFIED PROCESSES
C
      DO 10 M=0,PMLYRS
      K=PMLYRS+2-M
      DO 10 L=1,4
      XVLITR(K,L)=XVLITR(K,L)+XVLITR(K-1,L)*(1.-(1.-CVLTFR(K-1,L))
     1 **PMDT)
   10 XVLITR(K-1,L)=XVLITR(K-1,L)-XVLITR(K-1,L)*(1.-(1.-CVLTFR(K-1,L))
     1 **PMDT)
C
C  EACH TIME STEP DCMP ATTEMPS TO PARTIALLY DECOMPOSE ALL LITTER
C  CATEGORIES BUT STANDING DEAD.  STANDING DEAD IS DECOMPOSED ONLY
C  AFTER LITTER TRANSFER FUNCTION PUTS IT ON SURFACE.
C
C
      DO 30 I=2,PMN
C  SURFACE LITTER AND LITTER IN  1ST LAYER HAVE SAME WATER FACTORS.
      K=I-2
      IF(I.LE.2)K=1
      FF=F1(CWPSI(K),PDWW,4)*F1(XHSOLT(I-1),PDTT,4)*PMDT
```

```
      DO30J=1,4
      IF(XVLITR(I,J).LE.0.0)GOTO20
      F=1.-EXP(-FF*PDR(J))
C  F IS NOW THE FRACTION OF PRESENT LITTER CATEGORY DECOMPOSED THIS TIME
C  STEP.   USING EXPONENTIAL WILL USUALLY BE OVERKILL ON CORRECTNESS
C  (BUT ALSO MEANS IF F IS LARGE WE WON'T GET NEGATIVE VALUE GENERATED
C  IN ANY LITTER CATEGORY).
C
      CDDL(I,J)=XVLITR(I,J)*F
      XVLITR(I,J)=XVLITR(I,J)*(1.-F)
      GO TO 30
   20 CDDL(I,J)=0.0
   30 CONTINUE
C
C
C
C  DEBUGGING
      DBGFLG=.FALSE.
      IF(DEBUG1 .LT. 1.E-5) GO TO 40
      IF(MOD(((TIME-TSTART)/PMDT), DEBUG1) .LT. 1.E-5) DBGFLG=.TRUE.
   40 CONTINUE
      IF(.NOT. DBGFLG) GO TO 80
   50 WRITE(1,60)CDDL
       WRITE(1,70) ((XVLITR(K,KK),KK=1,4),K=1,PMN+1)
   60 FORMAT(' DD', 12F5.1, 5X, 12F5.1,/, ' DD', 12F5.1, 5X, 12F5.1)
   70 FORMAT(' D', 5(4F6.1,2X), /, ' D', 5(4F6.1,2X))
   80 CONTINUE
C
C  END DEBUGGING
C
C  THAT'S ALL FOLKS
C
      RETURN
C
CEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
CEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
      ENTRY DINIT
C
C  READ AND WRITE INPUT DATA AND COMMENTS
C
      READ(5,90)TDCCC
      WRITE(6,100)TDCCC
C
      READ(5,90)TDCCC
      WRITE(6,100)TDCCC
      READ(5,/)PDR
      WRITE(6,120)PDR
      WRITE(6,110)
C
      READ(5,90)TDCCC
      WRITE(6,100)TDCCC
      READ(5,/)PDWW
      WRITE(6,120)PDWW
      WRITE(6,110)
C
      READ(5,90)TDCCC
      WRITE(6,100)TDCCC
      READ(5,/)PDTT
      WRITE(6,120)PDTT
      WRITE(6,110)
C
      PMLYRS=PMN-2
      READ(5,90) TDCCC
      WRITE(6,100) TDCCC
      READ(5,/)((CVLTFR(J,K),K=1,4),J=1,PMLYRS+1)
      WRITE(6,/)((CVLTFR(J,K),K=1,4),J=1,PMLYRS+1)
      WRITE(6,110)
C
      READ(5,90)TDCCC
      WRITE(6,100)TDCCC
      READ(5,/)DEBUG1
      WRITE(6,120)DEBUG1
      WRITE(6,110)
C
      READ(5,90)TDCCC
      WRITE(6,100)TDCCC
      WRITE(6,110)
C
C
   90 FORMAT(20A4)
  100 FORMAT(' ',20A4)
  110 FORMAT(' ')
  120 FORMAT(' ',8F14.5)
C
C
      RETURN
      END
```