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**Documentation of TRU Biological Transport Model
(BIOTRAN)**

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DOCUMENTATION OF TRU BIOLOGICAL TRANSPORT MODEL (BIOTRAN)

by

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ABSTRACT

Inclusive of Appendices, this document describes the purpose, rationale, construction, and operation of a biological transport model (BIOTRAN). This model is used to predict the flow of transuranic elements (TRU) through specified plant and animal environments using biomass as a vector. The appendices are:

- A) Flows of moisture, biomass, and TRU**
- B) Intermediate variables affecting flows**
- C) Mnemonic equivalents (code) for variables**
- D) Variable library (code)**
- E) BIOTRAN code (Fortran)**
- F) Plants simulated**
- G) BIOTRAN code documentation**
- H) Operating instructions for BIOTRAN code**

The main text is presented with a specific format which uses a minimum of space, yet is adequate for tracking most relationships from their first appearance to their formulation in the code. Because relationships are treated individually in this manner, and rely heavily on Appendix material for understanding, it is advised that the reader familiarize himself with these materials before proceeding with the main text.

I. INTRODUCTION

Several documents^{1,2} have been completed which provide and/or describe capabilities, operating instructions, and code documentation of the TRU Biological Transport Model (BIOTRAN) developed for LASL. Previous LASL Progress reports,^{3,4,5} one other LASL report,⁶ and LASL presentations^{7,8,9} have provided limited preliminary documentation of model aspects including validation, stability, utilization capability, and sensitivity analysis. This report will provide the rationale used in the development and utilization of the model itself. Data obtained from field studies, or other data bases used in validating certain aspects of the model will be presented in another report. Hopefully, this report will put into perspective model capabilities, limitations, and usefulness of the model in predicting the movement of TRU and other radionuclides and nutrients through ecosystems using biomass as a vector.

II. BACKGROUND ON MODEL DEVELOPMENT AND UTILIZATION

A generalized description of BIOTRAN is presented in Figure 1 as it was generally conceived for application to a given grid of the study area,³ and was used as the basis for model development allowing some modification. The model was constrained to permit exchanges and transports of TRU between what were considered the most significant pathways. A modular approach was decided upon for realization of transport processes as indicated, however, some modifications, deletions, and consolidation of modules became necessary or more expedient as model development proceeded.⁴ All of the major components (Atmosphere, Lithosphere, Plants—ie) were included as part of the present model with exception of (MAN) which was left for possible future interphasing with modules of this type.¹⁰ The aquatic module of Hydrosphere was never initiated due to time constraints and other priorities. Other portions of Hydrosphere including transport of TRU through runoff and soil erosion were also not considered. The modeling efforts on Atmosphere^{3,4} with respect to predicting TRU air concentrations over a given grid of the study area were not included as part of the model in lieu of providing "scenario" capability for both chronic and acute TRU releases.¹

Efforts were also directed toward formulating inter-regional (grid) transport routes for TRU as described when an overall status report of module development was presented (Fig. 2);⁴ although inter-grid transport is not part of the present model, the description does indicate how the original conception of the model was changing to meet project needs, and can be used to compare with the final conceptual version of the model (Fig. 3). Hence, the present model provides output for modeling TRU transport to humans, but does not include the latter as such. In addition, other needs (modules) required for model operation, and module "lumping" into subroutines for codification has complicated the relationship between model components and coding arrangement as shown in Fig. 4.² The main program (PLANTS) carries all elements previously included in Lithosphere, Hydrosphere, Atmosphere, and most elements of Plants of the earliest model.³ The Plant component may require as many as three subroutines, depending on user options,¹ while all elements for Animal are located in one subroutine.¹ For this reason most modules developed are not separate entities, but are imbedded within larger groupings as submodules with varying degrees of dependence on each other for proper operation as will be shown later in this report.

BIOTRAN was constructed primarily to fulfill several project objectives:⁵

1. to model the movement of Transuranics (TRU) through ecosystems within the study area.
2. to provide enough generality for extending its use to other areas.
3. to be capable of predicting both short and long range cycling of TRU in a number of climatic regimes.
4. to provide output which could be used in evaluating potential hazards to man from Transuranics (TRU) as a result of waste storage and accidental releases.

Early in the modeling phase it was decided to model concomitantly:

1. flow of biomass
2. flow of water
3. flow of TRU

and to construct a mathematical model of intermediate complexity consisting primarily of:

1. *State variables*—model elements that comprise the system structure (compartments).
2. *Driving variables*—model elements which vary with time, affect flow of pool material, but are largely independent of the system.
3. *Intermediate variables*—model elements which control or affect flow of pool material from one state (compartment) to another.

Fig. 1.
TRU biological transport model.

Furthermore, it was decided that the flow structure of the model would best be represented mathematically as a set of difference equations based on daily iterations which would govern input and output of pool material within and among states involving all three types of variables mentioned. An illustration of such a strategy was reported on earlier, and illustrated (Fig. 5) for forage plants³ where the identification of principal flow effectors was described and given preliminary documentation. Subsequent development has followed this strategy as will be shown in the next section of this report; however, generalization, refinement, and sensitivity techniques were extended to all portions of the model at all times during the course of development.

Fig. 2.
Intraregional and interregional integration routes of TRU.

Fig. 3.
Present status of model development for single grid TRU transport.

Fig. 4.
Relationship between model components and model code.

Fig. 5.
Letters indicate physiochemical and biological processes. Numbers indicate transport rate; processes are listed in accompanying table.

Transport Rate No.	Description of Process	Controlling Variables Used in Determining the Specific Transport Rate
1	Precipitation to soil storage	Precipitation regulation, soil water
2	Surface run-off from soil	Soil water, temperature, live above ground biomass
3	Biomass production from photosynthesis	Soil water, live above ground biomass, temperature, insolation
4	Death of live above ground biomass	Soil water, live above ground biomass, temperature
5	Loss of Pu from above ground biomass (surface)	Precipitation regulation, time ^a
6	Production of litter and humus from standing dead	Above ground dead standing biomass, temperature, soil water precipitation regulation, above ground standing biomass
7	Loss of Pu from above ground dead biomass (surface)	
8	Loss of Pu from above ground standing biomass (surface), and deposition from atmosphere	Live above ground biomass, atmospheric Pu, time, precipitation regulation
9a,b	Loss of above ground standing biomass to grazers	Description in grazing module
10	Exchange of Pu and biomass between roots and above ground standing biomass	Live above ground biomass, root biomass, temperature
11	Loss of Pu from above ground dead standing biomass, and deposition from atmosphere	Dead above ground standing biomass, atmospheric Pu, time, precipitation regulation
12	Transport of Pu to soil from litter and humus	Litter and humus, temperature, soil water
13	Transport of Pu from soil to roots and roots to soil	Root biomass, soil Pu, temperature (root death)
14	Exchange of Pu between litter and humus (surface)	Litter and humus, atmospheric Pu, precipitation regulation time
15	Exchange of Pu between soil and atmosphere	Soil Pu, atmospheric Pu, precipitation regulation, time
16-18	Grazing model interfacing	Description of variables in grazing model

^aTime enters as variable as a removal decay constant based on dry deposition or resuspension of Pu.

III. STRATEGY USED FOR MODEL ANALYSIS

This document is written with the view that there is not a single analysis strategy which can be used to document a model. The work of IBP investigators¹¹ in this regard suggests a mathematical approach alluded to earlier which identifies flows, and catalogues variables of different types that affect transport mechanisms. However, not all model structure is easily amenable to such a strategy, and may even lead to confusion when operations other than flow are integral parts of a model such as this one. Yet a strict analysis of relationships utilized in a model without emphasis on system construction also may fall short of putting into perspective interrelationships between component parts. Hence, both types of strategies have been adopted for this report although the mathematical approach has been modified to integrate the two strategies more closely. Box-and-arrow diagrams indicating component arrangements will be decomposed into small, more manageable portions as necessary, rather than presenting the total model all at once. Certain conventions will be adopted; compartments (state variables) will be identified (X_i , $i = 1, n$) for a given pool (P); the units of flow will be specified. Flow diagrams will be presented such as:

where

(X_i) = names for a specific compartment (system)

(1,2) = compartment index: X_1 , X_2

P = gain or loss of exchanged material from the system

Several types of flows can be constructed from this example:

$F(P,1)$ = transport into X_1 from outside system (input)

$F(1,2)$ = transport from X_1 to X_2

$F(2,1)$ = transport from X_2 to X_1

$F(2,P)$ = transport from X_2 to outside system (sink)

Factors affecting flow can be indicated in functional form such as:

$F(I,K) = f(X_i, I_j, D_k)$

where

X_i = i th state variable

I_j = j th intermediate variable

D_k = D_k driving variable

These variables will be identified, catalogued, and related to the model code variable library (Appendix D), and code documentation (Appendix H). In addition, justification for the use of any or all factors affecting a flow of pooled material will be presented as required throughout the analysis. The other variables or their mnemonic equivalents:

C_1 = Lth constant

O_m = mth option or user decisions variable

L_n = nth logic or boundary variable

S_o = oth stochastic variable,

will complete the set of variables required for model documentation and are present in Appendix C. They include the location address in the code. Finally, instantaneous transport or exchange between compartments is represented as:

where the vertical dashed line indicates this type of transport, and $F(1 \cdot 2)$ instead of $F(1,2)$ is used to represent the function for transport of material from X_1 to X_2 , i.e. Other conventions used will be discussed as they arise. Mnemonic symbols will not be used in describing the flows as they are considered in this fashion in the code documentation (Appendix G).

The analysis will be performed first by identifying flows of pool material, and proceed to document the relationships as required. Water, biomass, and TRU flows will be considered in that order although parallel relationships between flows will be established as they occur; the order of documentation will follow as closely as possible that established in the code document (Appendix G). Variables which are functions of other variables (secondary variables) will be developed within the text as necessary.

The appendices included in this document are as follows:

Appendix A. Flows

Appendix B. Equations Involving Secondary Intermediate Variables

Appendix C. Variables and Their Mnemonic Equivalents

Appendix D. Variable Library

Appendix E. TRU Biological Transport Model Code (BIOTRAN)

Appendix F. Plant Number Positions

Appendix G. Code Documentation

Appendix H. Input Requirements

As an example of how the appendices may be used, consider the first flow in the *Water Flow Model*. In parentheses there will be a reference made to the appendix where the flow is located and the number in the appendix, i.e., (App. A, No. 1). The Flow $F(P,1)$ can then be found in Appendix A, number 1. For a secondary intermediate variable the same strategy will be used except that these variables will be found in Appendix B. In Appendices A and B the equation involving a flow or secondary intermediate variable will be stated, and the variables used will be defined for user convenience. Mnemonic names will not be used.

Appendix C contains variables discussed in this document and their mnemonic equivalents in the code are given as well as statement numbers where the mnemonic equivalent is defined.

Appendix D, Variable Library, contains only mnemonic names used in the actual code of the model. They have been defined for user convenience.

Appendix E contains the code of the TRU Biological Transport Model to be used with Appendices C, D, F, G, and H as well as having the actual program to reference.

Appendix F contains Plant Number Positions. In the program plants are simulated by punching a particular code in a position of an array that has 22 members. Positions 1 through 21 are listed with the particular plant that is being simulated.

Appendix G is the Code Documentation. This contains numbers of statements in order and what is being done within those statements.

Appendix H is the Input Requirements for running the program. Input cards are listed in the proper order, and input that is required or that is optional is indicated. Mnemonic names are used.

IV. WATER FLOW MODEL

The flow of water in the model is illustrated in Fig. 6. The flows $F(P,1)$ and $F(P,2)$ are dependent on several variable types:

$$F(P,1) = F(P,2) = f(D_1, I_1, S_1, I_2, S_2, S_3, I_4) \quad (\text{App. A, No. 1})$$

These flows represent transport of water from precipitation events to soil and snow compartments during a given calendrical day (I_5):

$$\begin{aligned} F(P,1) &= D_1 I_1 S_1 (1 + I_2 S_3) & I_5 &= |S_2| \\ &= 0 & I_5 &\neq |S_2| \end{aligned} \quad (\text{App. A, No. 2})$$

Fig. 6.
Water flow model.

The decision (L₁) which allocates precipitation as water or snow is based on daily temperature:

$$\begin{aligned} L_1 &= F(P,1) & D_2 &> 0 \\ &= F(P,2) & D_2 &= 0 \end{aligned} \quad (\text{App. B, No. 1}) (\text{Sec. III})$$

where the flows indicated are identical once (L₁) has been executed.

The flow of precipitation to soil (X₁), and snow (X₂) compartments is based on the total number of precipitation events occurring within a given area that exceeds 0.1 inch (I₄),¹² a rainfall distribution fraction by month (I₁),¹³ and an estimated coefficient of variation¹⁴ for the study area.

The second intermediate variable

$$S_1 = \frac{S_i}{\sum_{j=1}^{I_4} S_j} \quad (\text{App. B, No. 1}) (\text{Sec. IV})$$

where each S_i is a random number from an even distribution. The driving variable D₂ is based on a sinusoidal function:^{15,16}

$$D_2 = \frac{(I_7 - I_8)}{2} * \sin(2\pi * (I_6 - I_9)/365) + 1 + I_8 \quad (\text{App. B, No. 1}) (\text{Sec. II})$$

The temperature is corrected for elevation and latitudinal differences

$$D_2 = D_2 I_{10} * (I_{11} - I_{13}) \quad (\text{App. B, No. 2})$$

D₂ is converted to centigrade and varied stoichastically on a monthly basis.³

$$D_2 = (D_2 - 32) * 5/9 + S_3 * I_{14} \quad (\text{App. B, No. 3}) (\text{Sec. II})$$

The decision to represent temperature trends on a monthly basis was based on observation of weather reports, although this analysis was not exhaustive; other trend lengths greater than one day could have been used but not as easily incorporated into the model code. The flow F(2,1) is based on a snow melt function:¹⁷

$$F(2,1) = C_1 * X_2 \quad (\text{App. A, No. 3})$$

The flow F(1,P) is related to soil moisture status during any F(P,1) and F(1,2)

$$\begin{aligned} F(1,P) &= X_1 + P - I_{15} & X_1 + P &> I_{15} \\ &= 0 & X_1 + P &\leq I_{15} \end{aligned} \quad (\text{App. A, No. 4})$$

that is the moisture above the holding capacity in the top 250 mm of soil is lost to a runoff sink and not utilized in the model; adjustment for soil depth is considered in the next flow.

The flow $F(1,3 \cdot 4 \cdot 5)$ is related to soil depth, soil moisture, and ambient air temperature

$$\begin{aligned} F(1,3 \cdot 4 \cdot 5) &= I_{18} & X_1 &\geq I_{16} \\ &= I_{18} * S_1/I_{16} & I_{17} &\leq X_1 \leq I_{16} \\ &= 0 & X_1 &\leq I_{17} \end{aligned} \quad (\text{App. A, No. 5})$$

where

$$I_{18} = C_2 + C_3 * D_2^{.15} \quad (\text{App. B, No. 2})$$

The flow $F(P',1)$ is an "apparent" flow of moisture from lower soil depths (greater than 250 mm) to the upper 250 mm depth:

$$F(P',1) = (1 - I_3) * I_{20}, \quad (\text{App. A, No. 6})$$

where

$$I_3 = C_4 / (1 - \text{EXP}(-C_5 * I_{19})). \quad (\text{App. B, No. 1})$$

The latter factor was estimated from evapotranspiration studies of conifers in the Cascade Range,¹⁸ and is based on root distribution pattern and O_2 utilization strategies by these plants. The relationship has been extended to include all plants in the model. Finally, the flow $F(5,P)$ or evapotranspiration is numerically identical to root absorption: $F(1,3 \cdot 4 \cdot 5) = F(5,P)$. As indicated by the model, only those flows pertinent to biomass flow or nutrient uptake were considered in the water flow model.

V. BIOMASS FLOW

The flow of biomass in the model is central to all other model flows. Also, biomass attributes which may or may not affect biomass flow are also interphased with this model such as management, ruminant herd; i.e., biomass flow generally parallels TRU flow which occurs concomitantly with it. A diagram of biomass flow is presented in Fig. 7. Internal flows of biomass occur during program operation, whereas peripheral biomass flow requires user option. Attribute interphasing may affect flow for various competing plant types, but not for a single type itself. The different strategies for plant growth requires that internal flow adapt simultaneously to any group of plants under simulation. This will become apparent as flow characteristics are described and both intermediate variables (I), and different constants (C) are employed in specific situations.

The flow $F(P,5)$ or potential gross photosynthesis is represented by

$$\begin{aligned} F(P,5) &= X_6 * I_{21} * I_{22} * I_{23} & L_2 &= 1 \\ &= 0 & L_2 &= 0 \end{aligned} \quad (\text{App. A, No. 7})$$

LEGEND

RM = Ruminant	→ internal flow
NC = Niche Competition	- - - peripheral flow
SC = Succession	... attribute
FS = Forest Structure	— functional dependence
FM = Forest Management	
AG = Agricultural	
R = Roots	
ST = Stems	
L = Leaves	
DR = Dead Roots	
DLS = Dead Leaf-stem	
RL = Root Litter	
LSL = Leaf-stem Litter	

Flow Units = g/m²/day

Fig. 7.
Biomass flow and peripheral attributes.

where

$$I_{21} = 1 - (D_2 - C_8)^2 / C_7$$

$$D_2 > C_8$$

$$= 1 - (D_2 - C_8)^2 / C_8$$

$$D_2 \leq C_8$$

(App. B, No. 3) (Sec. II)

represents estimates of temperature effect on photosynthesis for different plant types within the model.^{18,19}

The effect of soil moisture on photosynthesis is determined as

$$I_{22} = 1 - \text{EXP}(- (C_9/I_{16} - I_{17})) * (X_1 - I_{17})) + 0.01 \quad (\text{App. B, No. 4})$$

where X_1 refers in this case to available soil moisture of the water flow model. This relation¹⁶ was adapted to plants other than perennial grasses by assessing their soil water dependence through tuning of the model, although more exhaustive investigations of this type are probably advisable for fine tuning of plants not directly comparable to those in the study area.

The effect of insolation on photosynthesis is described as follows:

$$I_{23} = C_{10} * D_3 \quad (\text{App. B, No. 5}),$$

where the daily insolation

$$D_3 = (I_{24} - I_{25}) * ((\text{Sin} * (2 * (I_5 - I_{26})/365)) + I_{25}) \quad (\text{App. B, No. 4}) (\text{Sec. II})$$

However, $D_3 \leq 450.0$, or is set to that value if greater in calculating (I_{23}) in agreement with IBP studies for light saturation of photosynthesis with Calvin type plants²⁰ which have maximum efficiencies of about 0.45 g $\text{CH}_2\text{O/g}$ leaf biomass in temperature zone.¹⁵ Plant respiration is represented by:

$$\begin{aligned} F(3,P) + F(4,P) + F(5,P) &= (X_5 + C_{11} * X_5) * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14} & L_3 &= 1 \\ &= 0 & L_3 &= 0 \end{aligned} \quad (\text{App. A, No. 8})$$

The gate (L_3) is used in conjunction with agricultural crops to simulate planting and harvesting periods. Also, if ($C_{11} = 0.0$) as it is for perennial grasses and other forage crops, then root respiration $F(3,P)$ is uncoupled from above ground biomass:

$$F(3,P) = 0.3 * X_3 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14}. \quad (\text{App. A, No. 9})$$

For agricultural crops ($C_{11} = 0.0$) root and stem respiration biomass components are all grouped under (X_5) or the leaf biomass itself. The maintenance biomass ($X_5 + C_{11} * X_5$) is observed to be equal to some multiple of leaf biomass (X_5). The decision to adopt this strategy for woody plants, and all plants in general was based on experimentation with other strategies relating sapwood thickness among conifers^{4,21} and other structural studies.² The most easily tuned strategy was adopted for simulating growth of Ponderosa pine ($C_{11} = 3.0$) and Pinon pine ($C_{11} = 5.0$) which indicated that maintenance biomass relative to leaf biomass increased with increasing adaptation to xeric environments as expected. Limited simulation experiments with Douglas-Fir ($C_{11} = 2.0$), and deciduous trees ($C_{11} = 1.5$) further support this strategy. The model thus functions by limiting growth rate and overall equilibrium biomass in tree species which have more water storage and absorbing potential, and therefore greater adaptability to xeric environments. More experimentation with the model in this regard is necessary.

The determination of leaf biomass in the model is not based on flow processes, but on a relationship depending on total above ground biomass for nonwoody plants:

$$X_5 = 0.928 * I_{27} * \text{EXP}(- 3.11 * I_{27}) + 0.072 * I_{27} \quad (\text{App. B, No. 2})$$

where

$$I_{27} = (X_4 + X_5) \text{ (App. B, No. 6);}$$

that is leaf biomass is calculated on a daily basis. The ratio of total leaf biomass to total above ground biomass (X_5/I_{27}) with increasing biomass density produces a reversed sigmoid type curve which becomes constant (0.072) at about 2000 g/m.² It is intended to simulate the transformation of an herbaceous type plant into a woody or pithy structure. Quantitative information of this type was not found in the literature although numerous information was available on related root/shoot biomass ratios. However, proper operation of the model for all types of plants does require a strategy of this type. Investigation of (X_5/I_{27}) ratios in selected plant types would be of great value in further verifying this strategy.

For woody perennial plants leaf biomass is limited by bud formation during the previous year

$$\begin{aligned} X_5 &= C_{15} * I_{28} & X_5 &\geq C_{15} * I_{28} \\ &= X_5 \text{ (previous calculation)} & X_5 &< C_{15} * I_{28} \quad \text{(App. B, No. 3) (Sec. V)} \end{aligned}$$

where I_{28} equals the running average annual productivity

$$i_{28} = \sum_{i=1}^{I_{30}} I_{29i}/I_{30} \quad \text{(App. B, No. 7)}$$

and the current year productivity (I_{28}) is related to actual net daily photosynthesis to be described later in this report. Whereas needle biomass in conifers is related to running average annual productivity in the model, leaf biomass in deciduous trees appears to be related to (1/2) of this quantity as judged by simulation experiments. Support for the conifer strategy comes from measurement of needle biomass density in different aged stands of Douglas Fir,²³ and an extensive study of a Ponderosa Pine forest;²⁶ the deciduous tree strategy is supported by leaf biomass estimates in a deciduous forest.^{24,26} In both cases the needle and leaf densities as well as productivities tend to reach or oscillate around an equilibrium value. A further control on leaf biomass for deciduous trees and shrubs is leaf drop:

$$\begin{aligned} X_5 &= X_5 & L_4 &= 1 \\ &= X_5 & L_4 &= 0; I_{31} + 1 < D_2 < I_{32} + 1 & \text{(App. B, No. 4) (Sec. V)} \\ &= 1.0 & L_4 &= 0; I_{31} + 1 > D_2 > I_{32} + 1 \end{aligned}$$

where leaf break and drop is simulated as an abrupt event at the beginning and end of frost-free period rather than a more gradual transition. This strategy was adopted to coincide with an average frost-free period or integral average growth activity period.

Actual net photosynthesis is estimated from potential net photosynthesis

$$I_{34} = F(P,5) - F(3,P) - F(4,P) - F(5,P) \quad \text{(App. B, No. 10)}$$

after a correction for water utilization efficiency for different plants at different times during the year. The amount (ml) of water required for each gram of photosynthate produced is estimated on a daily basis as $I_{38} = (C_{16} - C_{17}) / (I_{21} * I_{22})$ (App. B, No. 9), where the denominator is not allowed to fall below 0.01. Hence, the actual net photosynthesis is

$$\begin{aligned} I_{35} &= I_{34} * I_{36} * I_{37} & I_{33} * I_{34} &\leq I_{20} * 10^3 * I_{36} * I_{37} \\ &= I_{34} * I_{36}^2 * I_{37}^2 * I_{20} * 10^3 / (I_{33} * I_{34}) & I_{33} * I_{34} &> I_{20} * 10^3 * I_{36} * I_{37} \end{aligned}$$

(App. E, No. 11)

where

$$\begin{aligned} I_{36} &= I_{36} & O_2 &= 1.0 \\ &= 1.0 & O_2 &= 0.0 \end{aligned}$$

(App. B, No. 14)

and

$$\begin{aligned} I_{37} &= I_{37} & O_1 &= 1.0 \\ &= 1.0 & O_1 &= 0.0 \end{aligned}$$

(App. B, No. 16)

The intermediate variables (I_{36} , I_{37}) will be discussed when peripheral biomass flows are considered. The limitation of net photosynthesis by available water, and the utilization efficiency of the plant itself was observed to follow phenological development in range plants:²⁷ a sinusoidal function was adopted in a grassland simulation study based on this yearly event.¹⁵ However, for modeling purposes it was reasoned that since both ambient temperature and available soil moisture affect overall photosynthesis, then they also affect water utilization efficiency as well as phenological development. Substitution of the interaction term ($I_{21} * I_{22}$) into the model as described together with the maximum utilization efficiency given for range grasses yielded results which were in good agreement with the sinusoidal function previously adopted.¹⁵ Consequently, the relationship was extended to include other plant types as well. However, maximum utilization efficiencies for plants other than range grasses were found by tuning. Again the experiments yielded a trend which showed decreasing water utilization efficiencies as one proceeded from xeric to less xeric plants. Actual evapotranspiration studies on plants of these types are required for further verification. The new strategy eliminates phenological development relationships which follow soil-moisture temperature markers. Finally, current year productivity (I_{29}) mentioned earlier is summed on a daily basis

$$I_{29} = \sum_{i=1}^{365} I_{35i}$$

(App. B, No. 8)

for each day of a calendrical year. The latter includes both positive and negative (respiratory) estimates of (I_{35}). The second condition is present during the early growth phase of woody plants.

The flow $F(4,3)$ or transport of photosynthate to roots from above ground parts depends on the sign of net photosynthesis

$$\begin{aligned}
F(4,3) &= C_{18} * I_{35} & I_{35} &\geq 0 \\
&= I_{35} * (X_3 / (X_3 + I_{27})) & I_{35} &< 0
\end{aligned}
\tag{App. A, No. 13}$$

Photosynthate allocation of roots of grasses and trees^{16,24} were assigned according to what was estimated as the most probable allocation for the mature plant. All other allocations were determined from tuning experiments using grass and tree type plants as guides, and balancing with mortality losses to be considered. More information of this type is required for further verification.

The mortality flows F(4,7) and F(5,7) representing stem and leaf biomass mortality, respectively, follow different strategies depending on whether:

- 1) the plant type is evergreen or deciduous,
- 2) an annual or perennial grass,
- 3) a harvested crop other than grasses.

The combined flow:

$$\begin{aligned}
F(4,7) + F(5,7) &= \\
&0.693 * X_6 / 730 + I_{27} * I_{38} & \text{a. } O_6 = 0, L_5 = 0, L_4 = 1 \\
&I_{38} * I_{27} & \text{b. } O_6, L_5 = 0, L_4 = 0 \\
&I_{38} * I_{27} + X_6 & \text{c. } O_6 = 0, L_5 = 0, L_4 = 0, D_2 = I_{32} \\
&0.005 * I_{27} & \text{d. } O_6 = 0, L_5 = 1, L_4 = 0, C_{26} \leq D_2 \leq C_{21} \\
&I_{27} * (C_{20} * (D_2 - C_{21}) + C_{22} * 0.05) & \text{e. } O_6 = 0, L_5 = 1, L_4 = 0, D_2 > C_{21} \\
&I_{27} * (C_{23} - C_{24} * D_2) * 0.05 & \text{f. } O_6 = 0, L_5 = 1, L_4 = 0, D_2 < C_{26} \\
&0.1 * I_{27} & \text{g. } O_6 = 1, L_5 = 1, L_4 = 0, I_5 = I_{30}
\end{aligned}
\tag{App. A, No. 14}$$

The variable (I_{38}) is estimated as:

$$I_{38} = 2 / (365 * C_{37}) \tag{App. B, No. 18}$$

or the reciprocal of the mean average life span of the plant in question. The variable (I_{38}) is applicable only to harvested crops with the exception of pasture grasses and alfalfa. The remaining relationships account for mortality losses at extremes of temperature,¹⁵ or operate on a continuous basis as with conifers and evergreen shrubs. The conifer needles are estimated to have a half-life of two years,²⁵ while shrub evergreen leaves are assigned one year half-lives. The total leaf biomass of deciduous trees is added to litter yearly at the end of the frost-free period (I_{32}); one-tenth of above ground biomass (I_{27}) is converted to leaf plant material at harvest (I_{30}) for specific crops.

The flow F(3,6) is patterned after mortality losses of above ground biomass with some exceptions:

$$\begin{aligned}
 F(3,6) &= [F(4,7) + F(5,7)] * [X_3/I_{27}] & \text{a.} \\
 &= [F(4,7) + F(5,7)] * [X_3/I_{27}] + I_{38} * X_3 & \text{b.} \\
 &= X_3 * I_{38} & \text{c.} \\
 &= X_3 & \text{d.} \quad (\text{App. A, No. 15})
 \end{aligned}$$

where conditions:

- a. Plants (1,2,4,5,6,9,10,12,14,15,16,17,20,21), see App. F.
- b. Plants (7,19)
- c. Plants (3,8,11,13,18)
- d. Plants (1,2,12), $I_8 = I_{39}$

With the exception of annual and perennial grasses and several harvested crops, most of the plants have been modeled with the same root mortality strategy: proportional to above ground mortality losses; the entire root biomass is converted to dead roots at harvest. The differences between annual and perennial plants were determined by simulation experiments, although the latter was based on mortality losses of above ground parts.¹⁵

The flows F(7,9) and F(6,8) were modeled to be both temperature and soil moisture dependent:

$$F(7,9) = I_{40} * I_{41} * N_7 \quad (\text{App. A, No. 16}), \text{ and}$$

$$F(6,8) = I_{40} * I_{41} * X_8 \quad (\text{App. A, No. 17}), \text{ where}$$

$$I_{40} = 0.004 + 0.0032 * D_2 \quad (\text{App. B, No. 19}), \text{ and}$$

$$I_{41} = 1.0 + (1/(I_{16} - I_{17})) * (X_1 - I_{17}) \quad (\text{App. B, No. 20})$$

Both types of flows were modeled after decomposition studies of range grasses¹⁵ and extended to all types of plants including conifers. Although they would be expected to over-estimate pine needle decomposition rates, simulation experiments did not bear this out sufficiently to modify the relationship for these plants. This could possibly be due to the rather infrequent occurrence of precipitation combined with rather cold winter months which could be masking different decomposition rates among plants. More information and testing is required in this regard.

The decomposition rate of both root and above ground humus are also modeled similarly:

$$F(8,P) = X_8 * 0.3 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14} \quad (\text{App. A, No. 18})$$

$$F(9,P) = X_9 * 0.3 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14} \quad (\text{App. A, No. 19})$$

They are identical to the strategy used for determining root respiration rate in perennial grasses described earlier. Such a strategy assumes that humus decomposition or mineralization rate is equal to root cell respiration at the same temperature. Further experiments are required to fine tune this strategy with field observations of this type.

VI. TRU FLOW

The flow TRU in this model has been firmly coupled to both water and biomass flows discussed earlier. So little is known of the behavior of TRU in ecosystems that it was assumed advantageous to vector it with flows which were more easily modeled and understood, provided that the coupling was reasonable and accurate. In addition to concomitant flow of TRU with water and biomass flow, other cycling behavior involving the surface of soil and plants, and the atmosphere itself was incorporated into the model (Fig. 8). However, the latter component was modeled in concentration units, and has other constraints to be described.

The flow of TRU into the system is largely dependent on user options of several types:

$$\begin{aligned} F(P,12) &= I_{43} & L_6 > 0 \\ &= I_{44} & L_7 > 0 & \text{(App. A, No. 20)} \\ &= I_{45} & O_4 = 1, O_3 > 1, O_4 = 3 \end{aligned}$$

where I_{43} = TRU activity/m³ from card input for year (I_{46}) and day (I_5)¹ and I_{44} = Function AIRAC (C_{28} , I_{46} , I_5).^{1,2} The last option (I_{45}) involves peripheral flow and will be discussed later in this report.

The flow $F(12,P)$ is considered to be instantaneous on a daily basis:

$$F(12,P) = X_{12} = F(P,12). \quad \text{(App. A, No. 21)}$$

Air concentrations are not preserved nor partly preserved from one iteration to the next, but are generated daily. This includes TRU contributions to X_{12} from all other sources which will now be considered. The flow of TRU from the soil surface (upper 2 cm) is based on resuspension estimates for different fractional plant covers:

$$\begin{aligned} F(10,12) &= (3 \times 10^4 * (I_{42} * X_{10})) & I_{48} &= 0 \\ &= 0 & I_{48} &> 0 & \text{(App. A, No. 22)} \end{aligned}$$

where (I_{42}) indicates precipitation amounts, the constant (3×10^4 g) is the mass of 1 m² soil, 2 cm deep, and

$$I_{42} = 2.5 * \text{EXP}(-4.6 * I_{47}) \times 10^{-8} \quad \text{(App. B, No. 21)}$$

The latter varies between 2.5×10^{-8} /day for bare ground to 2.5×10^{-10} /day at 100% plant ground cover. The value at 16% ground cover corresponds to the resuspension rate estimated under desert conditions.²⁹ The value at 100% ground cover compares with estimates in deciduous forests;³⁰ resuspension is omitted during days when precipitation occurs.

Fig. 8.
TRU flow and peripheral attributes.

The estimate of plant cover (I_{47}) is obtained as follows:

$$I_{47} = (1 - \text{EXP}(-1.54 * I_{28}) * I_{141} \quad (\text{App. B, No. 22})$$

This estimate was made on the basis of tuning experiments with range grasses and conifers, and extended to other plants. More precise cover estimates for plant groupings, and for structural development of tree stands will be considered when peripheral flows are described.

The resuspension of TRU from plant surfaces is considered in an analogous fashion to soil resuspension:

$$\begin{aligned} F(11,12) &= I_{42} * X_{11} & I_{48} &= 0 \\ &= 0 & I_{48} &> 0 \end{aligned} \quad (\text{App. A, No. 23})$$

The depositional flow $F(12,10)$ is based on a wind deposition velocity of 450 m/day—one-half the national average because of the low annual precipitation in the study area.

$$\begin{aligned} F(12,10) &= 0.0021 * X_{12}/3 \times 10^4 & I_{48} &= 0 \\ &= 0.7 * X_{12} * (1 - \text{EXP}(-0.6518 * I_{48}))/3 \times 10^4 & I_{48} &> 0 \end{aligned} \quad (\text{App. A, No. 24})$$

However, on days when precipitation occurs, up to 70% is deposited,³¹ depending on the amount of precipitation received (I_{48}). The ingrowth type factor in the relationship is based on an estimated optimum size rain (8 mm) which produces the maximum deposition noted, and where larger precipitation events do not increase deposition appreciably.

The deposition of particulates containing TRU on plant surfaces is related to the leaf area index for the given plant (I_{49}):

$$\begin{aligned} F(12,11) &= 0.0021 * X_{12} * I_{49} * 0.67 & I_{48} &= 0 \\ &= 0.7 * X_{12} * (1 - \text{EXP}(-0.6518 * I_{48})) * I_{49} , & I_{48} &> 0 \end{aligned} \quad (\text{App. A, No. 25})$$

The leaf index I_{49} is estimated from a relationship established for conifer needles:³

$$I_{49} = 0.013 * I_{50} \quad (\text{App. B, No. 23})$$

where

$$\begin{aligned} I_{50} &= X_6 + X_7 & \text{a. Plants (1,2,3,7,8,11,12,13,18,19), see App. F} \\ &= X_6 & \text{b. Plants (4,5,6,9,10,14,15,16,17,20,21), see App. F} \end{aligned} \quad (\text{App. B, No. 24})$$

The plants considered under condition (a) are annual and perennial grasses, and crop plants where dead standing plant material may become appreciable; the deposition of TRU on leaf surfaces also assumes that about 67% of the particulates are retained under dry global fallout conditions.³³

The flow of TRU from plant to soil surfaces or washoff is partitioned into two strategies:

$$\begin{aligned} F(11,10) &= (0.693/30) * X_{11}/3 \times 10^4 & I_{48} &= 0 \\ &= 0.3 * X_{11} * (1 - \text{EXP}(-0.6518 * I_{48})/3 \times 10^4 & I_{48} &> 0 \quad (\text{App. A, No. 26}) \end{aligned}$$

Dry fallout is estimated to have a 30-day half-time residence on plant surfaces,²⁹ while during precipitation events, up to 30% of fallout may be removed.

Another source of resuspendable material is fine litter particles containing TRU in the flow:

$$\begin{aligned} F(9,12) &= I_{42} * X_9 & I_{48} &= 0 \\ &= 0 & I_{48} &> 0 \quad (\text{App. A, No. 27}) \end{aligned}$$

The fine litter-humus compartment also transports TRU into the soil surface (X_{10});

$$F(9,10) = 0.3 * X_9 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14}/3 \times 10^4 \quad (\text{App. A, No. 28})$$

The flow of TRU from the resuspendable horizon (X_{10}) to the next 250 mm soil horizon below is formulated as:

$$\begin{aligned} F(10,1) &= (0.693/700) * X_{10} * (3 \times 10^4/3 \times 10^5) & I_{48} &= 0 \\ &= 0.01 * (1 - \text{EXP}(-0.6518 * I_{48})) * X_{10} * (3 \times 10^4/3.75 \times 10^5) & I_{48} &> 0 \\ & & & (\text{App. A, No. 29}) \end{aligned}$$

Under dry conditions the flow of TRU from the resuspendable zone is estimated to occur with a 700-day half-life, although in earlier versions the model used a 70-day half-life.³⁴ The former value is assumed to compromise discrepancies in reported flow rates. However, the more rapid flow in the presence of precipitation (by as much as a factor of 10) does allow some adjustment based on rainfall events.

The flow $F(P,1)$ is not modeled; however, the presence of buried waste in various soil horizons or the discharge of TRU bearing solutions into soils would make this an important source of contamination. As with atmospheric inputs, TRU inputs into different soil levels $F(P,1)$ is provided by user input option.¹ The soil compartment has been partitioned into 31 sub-compartments below the 20 mm soil surface compartment (X_{10}); they consist of 250 mm deep horizons. The flow of TRU from these horizons to other compartments in the model is illustrated in Fig. 9. The determination of soil depth (I_{54}) has been specified. In addition, several other soil characteristics are supplied by the user: the TRU activity in the i th soil horizon ($I_{51,i}$) TRU uptake coefficient ($I_{52,i}$) and the root fraction in the i th soil horizon ($I_{53,i}$); they can also be given a homogeneous value throughout the soil horizons if desired.²

The flow of TRU to roots from soil is thus a summation of level contributions:

$$\begin{aligned} F(1,3) &= \sum_{i=1}^{I_{54}} I_{51,i} * I_{52,i} * I_{53,i} * X_5 * I_{20} * 10^3 & i &\leq I_{55} \\ &= 0 & i &> I_{55} \quad (\text{App. A, No. 30}) \end{aligned}$$

Fig. 9.
TRU flow through soil horizons.

where the extent of root penetration (I_{bs}) is calculated as:

$$\begin{aligned}
 I_{bs} &= (1 - \text{EXP}(-0.001 * (I_{46} - 1) * 365 + I_b)) * 9144 & C_{27} > 9.0 \\
 &= (1 - \text{EXP}(-0.001 * I_b)) * 9144 & C_{27} \leq 9.0 \quad (\text{App. B, No. 25})
 \end{aligned}$$

The rate of root penetration into the soil is an estimate based on exponential decrease of root biomass with depth in response to moisture and oxygen gradients.⁸⁶ The relationship used for specifying root fraction distribution in soils at different depths is estimated by the following equation when not otherwise specified by the user:

$$I_{57} = [\text{EXP}(-0.004 * 250 * (i - 1)) - \text{EXP}(-0.004 * 250i)] / \text{EXP}(-0.004 * I_{64})$$

where

$$(2 \leq i \leq I_{54}) \quad (\text{App. B, No. 27})$$

Investigation of this equation reveals that over 80% of tree roots are located in the upper meter of soil; (I_{55}) limits the penetration of annual plants to the upper 2/3 meter of soil for the most part.

The uptake of TRU by roots is controlled largely by actual evapotranspiration rate and current leaf biomass or leaf area index as described earlier; the uptake coefficient itself was estimated from tuning experiments involving clover cropping.³⁶ Further testing of this hypothetical strategy would be helpful in verifying of TRU uptake from soil via water flux.

There are two outflows of TRU from the roots: the flow into above ground parts $F(3,4\cdot5)$, and the mortality flow $F(3,6)$. The latter is parallel to biomass flow:

$$F(3,6) = X_3 * (F(3,6)/X_6)_b \quad (\text{App. A, No. 31})$$

where the term $(F(3,6)/X_6)_b$ is a biomass flow parameter described earlier.

By the same analogy the decomposition of dead roots and flow of TRU to humus is:

$$F(6,8) = X_6 * I_{40} * I_{41} \quad (\text{App. A, No. 32})$$

The flow of TRU from root humus to soil, however, is partitioned to different soil levels in proportion to root fraction at any given level:

$$F(8, X_{11}) = X_8 * I_{52,1} * 3 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14} \quad , \quad 2 \leq i \leq I_{54} \quad (\text{App. A, No. 33})$$

as determined by (I_{55}). This relationship allows the accumulation of TRU in specific soil levels although it may not be present initially in given root horizons.

The exchange of TRU from below ground to above ground components has been modeled as a hypothetical transport system involving photosynthate production, maintenance biomass and root/shoot ratio:

$$F(3,4\cdot5) = X_3 * I_{58} * I_{27}/I_{59} \quad (\text{App. A, No. 35})$$

where the exchange factor

$$I_{58} = \left[\left[I_{60}/(X_5 + C_{11} * X_6) \right] * \left[1 - I_{60}/(X_5 + C_{11} * X_6) \right] \right]_b \quad I_{27} > 1.0$$

$$= 0 \quad I_{27} \leq 1.0 \quad (\text{App. B, No. 28})$$

and the subscript (b) indicates biomass flow parameters under consideration as described earlier. The translocate term is conditional:

$$I_{60} = \left| F(4\cdot5,3) \right| \quad \left| F(4\cdot5,3) \right| \leq (X_5 + C_{11} * X_6)_b - 1.0$$

$$= (X_5 + C_{11} * X_6)_b \quad \left| F(4\cdot5,3) \right| > (X_5 + C_{11} * X_6)_b \quad (\text{App. B, No. 29})$$

The flow of TRU is dependent on the root translocation under the assumption that both positive and negative values of net photosynthesis cause a flow of phloem into roots either in response to respiratory or storage conditions. The flow is conditioned by the relative storage capacity of roots with respect to above ground parts; the latter is made inversely proportional to root/shoot ratios as shown. Furthermore, it is assumed that in their counter-current flows Xylem, and phloem elements exchange TRU as they do many nutrients⁸⁷ along their entire length; and therefore, flow is also somewhat dependent, although indirectly, to water flux or evapotranspiration process—etc., involved in plant growth rates. Another mechanism which is simulated by this strategy is the shunting of nutrients into roots during senescence or death of above ground biomass which occurs with perennial grasses. This process is mediated considerably in woody plants where appreciable storage occurs in the bole. Finally, the exchange is regulated during the early growth phases of plants when the root translocate/respiratory biomass ratio becomes significant or possibly greater than unity.

The flow of TRU from above ground parts as a result of mortality losses parallels biomass flow

$$F(4,7) + F(5,7) = (X_4 + X_5) * ((F(4,7) + F(5,7))/I_{27})_b \quad (\text{App. A, No. 36})$$

where (b) indicates biomass flow processes.

Also, the flow of TRU from litter to humus is modeled parallel to biomass flow:

$$F(7,9) = X_7 * I_{40} * I_{41} \quad (\text{App. A, No. 37})$$

It is of importance to note that mortality but not respiratory processes cause a flow of TRU in contrast to biomass flow which occurs as a result of both. Hence, the increase in TRU concentrations in a plant tissue is due to respiratory as well as flow process. Also, the ratio of TRU/biomass resulting from both flows can be used to give estimates of TRU concentrations for any given compartment where TRU and biomass occur concomitantly.

VII. PERIPHERAL FLOWS OF WATER, BIOMASS, AND TRU

The flow of TRU, biomass, and water through portions of the model which require user option to enter are termed peripheral flows. Within such processes one may increase the capabilities of flow prediction by formulating other attributes of plant biomass, or create other flows which are dependent on plant biomass as a driving variable. In addition, the capability of the model to simulate agricultural crops is dependent on this type of flow. Finally, peripheral flows interact with internal flows in a direct or indirect manner as will be described; the relationship between flows is illustrated in Figures 7 and 8. The means by which a user may access peripheral flows have already been described,¹ and some of the mechanics involved have been explained.² This section of the report will consider the rationale used in the development of these modules.

VIII. AGRICULTURAL PERIPHERAL FLOW

Some interactions involving agricultural flow have already been mentioned: it interacts with water and biomass flow directly. For each crop plant simulated the module requires:

- a) irrigation schedules (I_{911} , $i = 1, j$; $j \leq 16$)

b) harvesting schedules (I_{62i} , $i = 2, k$; $k \leq 8$)

c) water application (I_{63i} , $i = 1, l$; $l \leq 16$)

where (I_{65i}), and (I_{64i}) represent planting and final harvesting dates for annual crops, respectively.

Irrigation schedules and concomitant water application interact with *water flow* by periodically augmenting soil moisture:

$$\begin{aligned} X_1 &= X_1 + 25.4 * I_{63i} & I_5 &= I_{62k} \\ &= X_1 & I_5 &\neq I_{62k} \end{aligned} \quad (\text{App. B, No. 1) (Sec. V)}$$

where i = i th irrigation and water application. Planting dates if required and harvesting schedules interact specifically with biomass and TRU flow. The following *biomass flow* interactions are modeled (k corresponds to the number of harvests in one year:

$$\left. \begin{aligned} \text{a) } F(4,7) + F(5,7) &= 0.1 * I_{27} \\ \text{b) } F(3,6) &= X_3 \\ \text{c) } I_{27} &= 1.0 \\ \text{d) } X_3 &= 1.0 \\ \text{e) } F(P,4 \cdot 5) &= 0 \\ \text{f) } F(4,7) + F(5,7) &= 0 \\ \text{g) } I_{27} &= 20.0 \\ X_7 &= X_7 * (20/I_{27}) \end{aligned} \right\} \begin{aligned} &k = 2, I_5 = I_{62,1} \\ &k = 2; I_{65i} > I_5 > I_{64i} \\ &I_5 = I_{62k}; 2 < k \leq 8; I_{27} > 20.0 \end{aligned} \quad (\text{App. A, No. 38})$$

Analogous effects on *TRU flow* are:

$$\left. \begin{aligned} \text{a) } (X_4 + X_5) &= 0.0 \\ \text{b) } X_3 &= 0.0 \\ \text{c) } (X_4 + X_5) &= (X_4 + X_5) * (20/I_{27}) \\ \text{d) } X_3 &= X_3 * (20/I_{27}) \end{aligned} \right\} \begin{aligned} &k = 2; I_5 = I_{64k} \\ &I_5 = I_{62,k}; 2 \leq k \leq 8, I_{27} > 20.0 \end{aligned} \quad (\text{App. B, No. 10})$$

The interaction of the agricultural module with all the types of flows used in the model are observed to be mostly mechanical in nature where materials balance is preserved as a result of human intervention in crop growth.

IX. NICHE COMPETITION PERIPHERAL FLOW

This module allows interaction of plants which are competing for the same resources with a similar strategy such as warm and cool season grasses; i.e., the interaction affects overall photosynthate production on a daily basis. Its effect on TRU flow is indirect, and has no effect on water flow as it now developed. Its effect on net photosynthesis for a given plant was estimated earlier as

$$I_{35} = I_{35} * I_{36} * I_{37} \quad (\text{App. B, No. 12})$$

The competition factor involves a relative photosynthetic efficiency factor based on leaf biomass and other factors

$$I_{361} = \left[(I_{351} / (C_{271} * X_{51})) \right] / \sum_{k=1}^n I_{35k} / C_{27k} : X_{5k} \quad I_{35} > 0 \quad (\text{App. B, No. 15})$$

$$= 1.0 \quad I_{35} \leq 0$$

where n = total number of plants in competition.¹ The successional life-spans (C_{27}) have been found by tuning to be meaningful in simulating succession and will be discussed later in this report. The competition module has not been tested for plant groupings other than for warm and cool season grasses.⁹ Successional half-life terms have been equal for both types of plants. Validation experiments of this type are being planned to test this module with other plant groupings.

X. SUCCESSION PERIPHERAL FLOW

When accessed this module affects biomass flow directly on an annual basis through the production of a succession factor (I_{37}) which is used to adjust net daily photosynthesis:

$$I_{351} = I_{351} * I_{361} * I_{371} \quad (\text{App. B, No. 13})$$

The factor is related to total biomass, and successional life-span as a first approximation, and is the basis upon which the plants within a group are ranked according to successional advantage: the first ranking plants in the series have the maximum value of the annual running average ranking factor:

$$I_{561} = \sum_{k=1}^{I_{46}} \left[(I_{271} + X_{31} + X_6 + X_7 + X_8 + X_9) / C_{271} \right] / \sum_{k=1}^{I_{46}} k \quad (\text{App. B, No. 26})$$

the first ranking plant has the second largest value of I_{56} —etc., for (K) plant groups. After obtaining a ranking 1,2,3— k , a minimum cover factor is obtained for each group as follows, depending on rank:

<u>Plant</u>	<u>Rank</u>
$I_{671} = I_{471}$	1
$I_{67j} = I_{47j} * (1 - I_{671})$	2
$I_{67i} = I_{47i} * (1 - 67i - I_{67j})$	3
.	.
.	.
.	.
$I_{67m} = I_{47m} * (1 - I_{671} - I_{67j} - ... I_{67m})$	m
	(App. B, No. 31)

A potential succession factor is obtained for each plant by taking the product:

$$I_{681} = (I_{671}/I_{471}) * (I_{681}/I_{69}) \quad (\text{App. B, No. 32})$$

The actual succession factor is estimated as:

$$I_{37} = I_{681} / \sum_{k=1}^m I_{68k} \quad (\text{App. B, No. 17})$$

The strategy for estimating a succession factor is thus observed to involve:

- 1) a ranking of plants with a factor which is directly proportional to structural biomass, and inversely proportional to life-span
- 2) estimation of potential cover which could be occupied by all plants specified with those plants having the highest rank receiving first priority,
- 3) the calculation of a succession factor based on the ratio between the occupied cover and the potential cover which a plant would have without competition,
- 4) adjustment of the succession factor by a term which allows less successful types to occupy residual area not occupied by the dominants.

This strategy was developed and found satisfactory for simulating succession in ponderosa and pinon-juniper woodlands. It is currently being verified, and more validation is planned in the future for this hypothetical scheme.

XI. HERBIVORE PERIPHERAL FLOW

This module affects both biomass and TRU flow strategies involved in the simulation of a ruminant herd. The module is divided into several different strategies for discussion purposes:

- a) Food preference and feeding strategy
- b) Herd and grazing characteristics

c) Rumen function and animal growth

d) TRU uptake characteristics

The food preference scheme involves the classification of forage plants into groups depending on dietary choice:

$$\begin{aligned}
 I_{711} &= 0.7, i = 1 & I_{70j,k} &= 1 \\
 &= 0.2, j = 2 & I_{70j,k} &= 2 \\
 &= 0.1, i = 3 & I_{70j,k} &= 3
 \end{aligned}
 \tag{App. B, No. 33}$$

where $(1 \leq i \leq 3)$, $(1 \leq j \leq 21)$, $(1 \leq k \leq 4)$, and when $I_{70j,k} = 4$, it refers to supplementary feed plants that will be considered later in this report. The preference fractions were estimated from reviews of food habits of wildlife.^{38,39} The total amount of forage available within each classification is estimated assuming a 3:1 preference of green to dry forage by the given animal:¹⁵

$$I_{721} = \sum_{j=1}^{I_{731}} [(I_{74j}) * X_{5j} + (1 - I_{74j}) * X_{7j} * X_{5j}/I_{27j}] * I_{76j}
 \tag{App. B, No. 36}$$

for all plants (j) included within the ith preference scheme, and where,

$$I_{74j} = 3 * X_{5j} / (3 * X_{5j} + X_{7j} * X_{5j}/I_{27j})
 \tag{App. B, No. 37}$$

$$I_{76j} = (1 - \text{EXP}(-0.167(X_{5j} + X_{7j} * X_{5j}/I_{27j})))
 \tag{App. B, No. 38}$$

It should be noted that up to three preference classes are possible for native forage (I_{731}); however, it is possible that only one or two of these preferences are required. The preference fractions are then recalculated as:

$$I_{711} = 0.78$$

$$I_{712} = 0.22 \qquad I_{733} = 0 \qquad \tag{App. B, No. 34}$$

$$I_{711} = 1 \qquad I_{732} = 0.0, I_{733} = 0.0 \qquad \tag{App. B, No. 35}$$

Both (I_{74}) and (I_{76}) for different plants are estimated from grassland forage;¹⁵ the utilization factor does not allow foraging of plants to the point of extinction of biomass density for any given plant species considered in the simulation. Having estimated the total biomass density available for foraging in three preference classes (I_{73}), other characteristics of the forage "mix" are estimated as weighted averages. These include:

- a) nitrogen content of consumed forage
- b) fraction of green biomass consumed
- c) TRU specific activity in forage
- d) TRU specific activity on forage surfaces
- e) supplementary feed

These characteristics must be determined individually for all plants considered as forage prior to obtaining the weighted averages required.

The nitrogen content for each plant is related to the growth rate of edible portions;¹⁵ in this model it is considered the ratio of above ground translocate to the leaf biomass on a daily basis:

$$\begin{aligned} I_{781} &= C_{19} * I_{36}/X_6 & I_{781} &> -0.05 \\ &= 0.0 & I_{781} &\leq -0.05 \end{aligned} \quad (\text{App. B, No. 39})$$

The nitrogen content of current photosynthate is estimated as:

$$\begin{aligned} I_{771} &= 3.0 & I_{781} &> 0.142 \\ &= (10.9) * I_{781} + 1.436 & I_{781} &\leq 0.142 \end{aligned} \quad (\text{App. B, No. 40})$$

The nitrogen content of standing green biomass is estimated as

$$I_{781} = I_{781} * (I_{791}/X_{81}) + (1 - I_{791}/X_{81}) * I_{771} \quad (\text{App. B., No. 41})$$

where previous day leaf biomass is transformed as

$$\begin{aligned} I_{791} &= I_{791} & I_{791} &< X_{81} \\ &= (X_{81})^2/I_{791} & X_{791} &\geq X_{81} \end{aligned} \quad (\text{App. B., No. 42})$$

for use in the relationship, and allows the proper symmetry of the equation to prevail. The nitrogen content of consumed forage is thus

$$\begin{aligned} I_{881} &= I_{741} * I_{791} + (1 - I_{741}) * C_{31} & I_{781} &> C_{31} \\ &= C_{31} & I_{781} &\leq C_{31} \end{aligned} \quad (\text{App. B., No. 30})$$

where the content is not allowed to fall below that of dry forage. The water content of the forage may also be estimated:¹⁶

$$I_{1821} = 30 * I_{781} \quad (\text{App. B, No. 96})$$

The weighted fraction of green biomass in the ingesta of a given ruminant may be estimated if sufficient forage in each preference class is available. The amount of forage consumed from each preference group is estimated as

$$I_{801} = I_{711} * I_{811} \quad (\text{App. B, No. 43})$$

where I_{811} refers to intake by an animal of a given age category within the herd to be described later in this report.

The weighted nitrogen content of ingested forage over all preference groups for each age group of a given animal type is:

$$I_{82k} = \sum_{i=1}^n (I_{80i}/I_{81k}) * \sum_{j=1}^{I_{72}} (I_{151j})/I_{72} \quad (\text{App. B, No. 44})$$

where,

$$I_{151j} = I_{86j} * (X_{8j} * I_{74j} + (1 - I_{74j}) * X_{7j} * X_{8j}/I_{27j}) * I_{75j} \quad (\text{App. B, No. 95})$$

where the jth plant is in the ith food preference.

In similar fashion the fraction of ingesta as green biomass is estimated as

$$I_{83k} = \sum_{i=1}^n (I_{80i}/I_{81k}) * \sum_{j=1}^{I_{73i}} I_{84j}; \quad (1 \leq n \leq 3) \quad (\text{App. B, No. 46})$$

and

$$I_{84j} = I_{74j} * X_{8j} * I_{78}/I_{72} \quad (\text{App. B, No. 47})$$

for all plants (j) within the ith preference scheme.

Parallel types estimated for TRU specific activity of external and internal origin are given as

$$I_{85k} = \sum_{i=1}^n (I_{80i}/I_{81k}) * \sum_{j=1}^{I_{73}} I_{86j} \quad (\text{App. B, No. 48})$$

$$I_{87k} = \sum_{i=1}^n (I_{80i}/I_{81k}) * \sum_{j=1}^{I_{73}} I_{88j} \quad (\text{App. B, No. 50})$$

respectively, where

$$I_{86j} = I_{75j} * I_{74j} * ((X_8 * (X_{4j} + X_{8j})_p + (1 - I_{74j}) * X_7 * X_8 * (X_7)_p/I_{27})I_{72} \quad (\text{App. B, No. 49})$$

$$I_{88j} = I_{75j} * I_{74j} * ((X_8 * X_{11j})_p + (1 - I_{74j}) * X_7 * X_8 * (X_{11j})_p/I_{27}/I_{72}) \quad (\text{App. B, No. 51})$$

and (p) subscript indicates TRU pool; others refer to biomass pool. The variables ($I_{81}, I_{82}, I_{88}, I_{86}$, and I_{87}) are required for the simulation of rumen function to be described later in this report.¹⁶

Another source of forage included in the model is that of supplementary feed crops which are also simulated. Harvesting schedules are used to gate accumulation of supplementary feed of various kinds throughout the year for a given animal type:

$$I_{89m} = \sum_{i=1}^{I_{78}} (I_{27} - 20 + ((I_{27} - 20)/I_{27}) * I_{90i} * 4047 \quad (\text{App. B, No. 52})$$

for all plants. In addition, the specific activity of TRU in supplementary feed is estimated as

$$I_{91m} = \sum_{i=1}^{I_{73}} ((X_{4i} + X_{6i} + X_{7i})_p / (I_{27i} + X_{7i}) * (I_{27i} - 20) / I_{27i}) * X_{7i} * X_{90i} * 4047$$

(App. B, No. 53)

and on supplementary feed as

$$I_{92m} = \sum_{i=1}^{I_{884}} (X_{11i} / (I_{27i} + X_{7i})) * (I_{27i} - 20 + ((I_{27i} - 20) / I_{27i}) * X_{7i} * X_{90i} * 4047$$

(App. B, No. 54)

Previous year harvests and specific activities are preserved as (I_{98}), (I_{94}), and (I_{90}) for total biomass, TRU specific activity in plant, and TRU specific activity on the surface of the plant, respectively. These and current year values are used to estimate the TRU specific activities in and on plants on a daily basis for consumption:

$$I_{96m} = (I_{91m} * I_{89m} + I_{94m} * I_{93m}) / (I_{89m} + I_{93m})$$

(App. B, No. 55)

$$I_{97m} = (I_{92m} * I_{89m} + I_{95m} * I_{93m}) / (I_{89m} + I_{93m})$$

(App. B, No. 56)

The amount of supplementary feed required for domestic animals on a daily basis will be discussed later in this report.

The relationship between forage related intermediate variables and flow of biomass and TRU into a simulated ruminant herd is shown in Fig. 10 for one animal from a specific age group. Whereas biomass type input (I_{81} , I_{89}) is required for simulating biomass flow, other attributes of forage including nitrogen content and green biomass fraction also affect biomass flow into the herd. TRU flow largely parallels biomass; however, additional compartments are required to model TRU transport from soil and the atmosphere (I_{98}).

The simulated herd is characterized^{1,2} by

- a) herd size
- b) population structure
- c) biomass structure
- d) metabolic strategy

Herd size (I_{100j}) is variable depending on yearly (L_8) and daily (L_9) gates supplied by the user.^{1,2} The population structure is based on an estimated livestock structure or wild ruminant structure (C_{32j}). Hence, the number of animal units of a given age group

$$I_{101j} = C_{32j} * I_{100j}$$

(App. B, No. 57)

where j refers to the jth age group within the herd. The biomass of an animal unit within each age group is estimated initially by the relationship, $C_{33j} * I_{101j}$, where j refers to the jth age category.

The metabolic strategy used in this model is to simulate rumen function¹⁶ in one animal unit of each age group and to apply the result to all other animal units within the age group. Hence, all animal units within a given age group are considered identical, and materials balances of TRU and biomass are based on multiples of a single estimate in each case.

Fig. 10.
 Biomass and TRU flow in a ruminant herd animal.

Rumen function itself operates on a daily basis and is highly dependent on forage attributes described previously. The rumen may be described as compartment which has a certain capacity for forage that increases with animal unit biomass increase:

$$I_{104i} = 0.16 * I_{103i} \quad (\text{App. B, No. 59})$$

where initially,

$$I_{103i} = [C_{33i} * I_{102i}]^{0.76},$$

and thereafter,

$$I_{103i} = [X_{14i}]^{0.76} \quad (\text{App. B, No. 58})$$

for the i th age group.

The amount of forage consumed by the animal unit on a given day is:

$$F(P,13) = I_{81} = (I_{104k} - I_{110k}) (1.0 - 0.3 * I_{82}) \quad (\text{App. A, No. 39})$$

$$I_{110i} = X_{13i} + X_{18i} + 0.001 * X_{18i} \quad (\text{App. B, No. 63})$$

The digestible portion of intake is related to green-dry fractions in the forage:

$$F(13,17) = I_{105} = (1 - I_{83i}) * 0.45 + I_{83i} * 0.7 \quad (\text{App. A, No. 40})$$

The total amount of energy derived from this fraction is:

$$I_{108} = I_{105} * I_{81} * 4300 \quad (\text{App. B, No. 60})$$

The microprotein derived from the intake is related to the nitrogen content (I_{82}), and the energy derived from the digestible fraction:

$$F(13,16) = I_{107} = I_{108} * I_{153} \quad (\text{App. A, No. 41})$$

where

$$\begin{aligned} I_{153} &= 0.456 & I_{82i} &\geq 1.8 \\ &= 0.023 * (I_{82i} - 0.6) + 0.0186 & 0.6 &\leq I_{82i} < 1.8 \\ &= 0.031 * I_{82i} & 0 &\leq I_{82i} < 0.6 \end{aligned} \quad (\text{App. B, No. 97})$$

and

$$\begin{aligned} I_{82i} &= I_{82i} & I_{82i} &> C_{31}, i > 1 \\ &= 3.0 & i &= 1 \\ &= C_{31} & I_{82i} &\leq C_{31}, i > 1 \end{aligned}$$

The nitrogen level in forage is not allowed to drop below that in dry forage (C_{91}); also the nitrogen content of forage for the first age group is maintained at a level estimated from consumption of milk during weaning. The total amount of microprotein in the rumen initially is set at:

$$X_{101} = 200 * C_{91} \quad (\text{App. B, No. 5})$$

The flow of microprotein from the rumen to the humus compartment is:

$$F(16,9) = (0.52 * X_{101}) * 0.75 \quad (\text{App. A, No. 42})$$

The fermentation digestion rate is related to microprotein/metabolic weight ratio:

$$I_{1001} = (X_{101}/I_{1091}) * 0.04 \quad (\text{App. B, No. 61})$$

The rumen exit rate is thus:

$$\begin{aligned} I_{109} &= 0.25 + I_{108} & I_{108} &\leq 0.95 \\ &= 0.95 & I_{108} &> 0.95 \end{aligned} \quad (\text{App. B, No. 62})$$

where, however, a certain fraction of the passed food is fermented and is considered potentially digestible. The net flow of digestible material is thus incremented as:

$$F(13,17) = F(13,17) + I_{1001} * I_{1081} * F(13,17) \quad (\text{App. A, No. 43})$$

The exit of the digestible forage portion from the rumen is then estimated as:

$$F(17,9) = (I_{1001} * X_{17}) * 0.75 \quad (\text{App. A, No. 44})$$

The flow of undigested food from the rumen is estimated as:

$$F(13,9) = (I_{1081} * X_{18}) * 0.75 \quad (\text{App. A, No. 45})$$

The fraction of fermentation products as fatty acids is a function of the nitrogen content of the forage intake:

$$\begin{aligned} I_{111} &= 0.747 - 0.15 * (I_{821} - 0.6) & 0.6 &\leq I_{821} \leq 1.8 \\ &= 0.747 & I_{821} &< 0.6 \\ &= 0.591 & I_{821} &> 1.8 \end{aligned} \quad (\text{App. B, No. 64})$$

The total energy derived from fatty acid metabolism is estimated as:

$$I_{112} = I_{108} * I_{1001} * I_{111} \quad (\text{App. B, No. 65})$$

The total energy derived from passed food is estimated as:

$$I_{118} = [0.25 * (F(13,9) + F(17,9))] * 4300 \quad (\text{App. B, No. 66})$$

The total energy derived from microprotein is:

$$I_{114} = 0.65 * X_{16} * 4.3 * 0.52 \quad (\text{App. B, No. 67})$$

The total amount of energy available for metabolism is thus:

$$I_{115} = I_{112} + I_{113} + I_{114} - 125 * I_{1081} \quad (\text{App. B, No. 68})$$

The present strategy for supplementary feeding is made applicable while an animal is actively grazing in the simulation or is on supplementary feed. It may interact with gains or losses by an animal unit and affect TRU flow. The amount of supplementary feed is averaged over the grazing periods, and is set equal to the basal respiratory term in mass equivalents on a daily basis for animals not on range:

$$I_{1161} = 125 * I_{1081}$$

or

$$I_{1161} = I_{115} \quad (\text{App. B, No. 69})$$

for animals on range when respiration exceeds caloric intake.

The weight gain by an animal unit depends on its biomass relative to the biomass of a mature weight animal unit. The additional maintenance factor is estimated as:

$$\begin{aligned} I_{1171} &= \infty & I_{120} &\geq 1.0 \\ &= 3.74 + 10.52 * I_{120} & 0.75 &\leq I_{120} < 1.0 \\ &= 3.74 + 5.26 * I_{120} & 0.5 &\leq I_{120} < 0.75 \\ &= 1.5 & 0.0 &\leq I_{120} < 0.5 \end{aligned} \quad (\text{App. B, No. 70})$$

where,

$$I_{118} = X_4 / (C_{33g} * I_{1021}) \quad (\text{App. B, No. 71})$$

The actual weight gain by an animal unit on a daily basis is:

$$\begin{aligned} F(13 \cdot 16 \cdot 17, 14) &= 0.0 & I_{1171} &= \infty \\ &= I_{1161} / 1700 & I_{1171} &\leq 0.0 \\ &= I_{1161} / I_{1171} * 1700 & 0 &\leq I_{1171} < 1.0 \end{aligned} \quad (\text{App. A, No. 46})$$

The total amount of forage consumed by an animal in a given age group may now be estimated as:

$$I_{1181} = I_{88k} * I_{81k} * 1000 + (1 - I_{88k}) * 1000 \quad (\text{App. B, No. 72})$$

and the number of meters grazed is estimated as:

$$I_{119l} = I_{118l} \sum_{j=1}^3 I_{72j} \quad (\text{App. B, No. 73})$$

and the total number of m² grazed by all animals units of a given age class is:

$$I_{120l} = I_{119l} * C_{82l} * I_{101l} \quad (\text{App. B, p. 13, No. 74})$$

The number of animal units/grazed area for an age group (i) is:

$$I_{121l} = I_{101l} / (I_{122l} * C_{34}) \quad (\text{App. B, No. 75})$$

The latter is used to estimate the amount of biomass removed from each plant type in the forage scheme:

$$F(4 \cdot 5, 13 \cdot 16 \cdot 17) = I_{83k} * (I_{123l} / I_{72m}) * (I_{80m} / I_{80k}) * I_{121k} \quad (\text{App. A, No. 47})$$

where

$$I_{123l} = (I_{74l} * X_{8l} + (1 - I_{74l}) * X_{7l} * X_{8l} / I_{27l}) * I_{78l} \quad (\text{App. B, No. 76})$$

Also:

$$F(7, 13 \cdot 16 \cdot 17) = (1 - I_{88k}) * (I_{123l} / I_{72m}) * (I_{80m} / I_{80k}) * I_{121k} \quad (\text{App. A, No. 48})$$

TRU flow in the module is concomitant with biomass flow and is concerned primarily with the transport across the rumen wall. As described earlier TRU uptake is divided into supplementary and native forage pathways. The total amount of TRU ingested from native forage is estimated as:

$$I_{124k} = (I_{100k} / I_{128k}) * (I_{118k}) * (I_{88k} + I_{87k}) + ((I_{128k} - I_{100l}) / I_{128k}) * (I_{118k}) * (I_{91k} + I_{92k}) * I_{128} \quad (\text{App. B, No. 77})$$

If respiration exceeds caloric intake, then the TRU uptake is incremented by:

$$I_{124l} = I_{124l} + |I_{118l} / 4.3| * C_{82l} * (I_{91k} + I_{92k}) * I_{128} \quad (\text{App. B, No. 78})$$

The total amount of supplementary feed consumed by a given age group is:

$$I_{128k} = I_{118k} * ((I_{128k} - I_{100l} / I_{128k}) * C_{82l} \quad (\text{App. B, No. 79})$$

If respiration exceeds caloric intake, then consumed feed is incremented as:

$$I_{128l} = I_{128l} + I_{100j} * |I_{118l} / 4.3| * C_{82k} \quad (\text{App. B, No. 80})$$

The TRU flow from green biomass into the rumen is:

$$F(4.5,13.16.17) = (X_4 + X_5) * (F(4.5,13.16.17))_b / I_{27} \quad (\text{App. A, No. 49})$$

where the (b) subscript indicated biomass flow. Similarly, TRU flow from dry biomass is:

$$F(7,13.16.17) = (X_7) * (F(7,13.16.17)/X_7)_b \quad (\text{App. A, No. 50})$$

and

$$F(11,13.16.17) = X_{11} * [(F(7,13.16.17) + F(4.5,13.16.17)/I_{27} + X_7)]_b \quad (\text{App. A, No. 51})$$

which is the transport from plant surfaces into the rumen. In this module the flow of TRU into the rumen from soil depends on the type of plant being consumed. For a given plant the amount,⁴⁰ of soil ingested while foraging is estimated:

$$\begin{aligned} I_{128k} &= 0 & L_5 &= 0 \\ &= (I_{80l}/I_{73k}) * X_{14k} * 3 & L_5 &= 1, I_{27} + X_7 < 20 \\ &= (I_{80l}/I_{73k}) * X_{14k} * 20/(I_{27} + X_7) & L_5 &= 1, I_{27} + X_2 \geq 20 \end{aligned} \quad (\text{App. B, No. 81})$$

The flow of TRU into the rumen is:

$$F(10,13.16.17) = I_{128k} * C_{32k} * I_{100j} * X_{10} \quad (\text{App. A, No. 52})$$

The flow of TRU from soil across the rumen wall is estimated as:

$$F(10.13.16.17,14) = I_{128k} * 0.001 * X_{10} \quad (\text{App. A, p. 10, No. 53})$$

The flow of TRU into the lungs from the atmosphere is estimated from a human model:⁴¹

$$F(12,18) = 0.15 * X_{12} * I_{129l} - 4.34 \times 10^{-4} * X_{18} \quad (\text{App. A, No. 54})$$

The flow of TRU from the pulmonary region of the lungs to the gut and across the rumen wall is:

$$F(18.17.16.13,14) = 1.38 \times 10^{-4} * 0.001 * X_{18} \quad (\text{App. A, pp. 10-11, No. 55})$$

The flow of TRU directly across the alveolar membrane is estimated as:

$$F(18,14) = 3.61 \times 10^{-3} \times X_{18} \quad (\text{App. A, No. 56})$$

Also, the flow of TRU across the rumen wall from nonpulmonary deposits is estimated as:

$$F(12.17.16.13,14) = I_{129l} * X_{12} * 0.35 * 0.001 \quad (\text{App. A, No. 57})$$

Finally, the flow of TRU across the rumen from consumed forage:

$$F(5.7.17.16.13,14) = 0.001 * F(10,13.16.17) \quad (\text{App. A, No. 58})$$

TRU flow which enters the rumen from all sources and is not assimilated is considered as activity associated with the humus compartment (X_9):

$$F(13 \cdot 16 \cdot 17, 9) = F(10 \cdot 13 \cdot 16 \cdot 17, 14) + F(18 \cdot 17 \cdot 16 \cdot 13, 14) \\ + F(12 \cdot 17 \cdot 16 \cdot 13, 14) + F(5 \cdot 7 \cdot 17 \cdot 16 \cdot 13, 14) / (0.999 * I_{122t} * C_{34t})$$

(App. A, No. 59)

TRU flow to milk is estimated as:

$$F(14, 15) = X_{14t} * C_{32t} * 0.001 / I_{180t} * 0.9 \quad i \geq 3 \\ = 0 \quad i < 3$$

(App. A, No. 60)

where

$$I_{180t} = (0.07 * X_{14t})^{0.84}$$

(App. B, No. 82)

the flow of TRU from milk is set at:

$$F(15, P) = 1$$

(App. A, No. 61)

The concentrations of TRU in several tissues of the herd are estimated by weighting of concentrations in specific age groups.² The tissues are:

- 1) TRU activity/animal unit in breeding herd (3-8 year olds)
- 2) TRU activity/animal unit in total herd
- 3) TRU activity/Kg in muscle tissue of herd
- 4) TRU activity/Kg in liver tissue of herd
- 5) TRU activity/Kg in bone tissue of herd
- 6) TRU activity/animal unit in newborn herd

The calculations assume that about 10%, 45%, and 45% of the TRU reside in muscle, liver and bone, respectively. The concentration in newborn is assumed to be 1/1000 of the TRU concentration in the breeding herd.

Biomass of some organs are power function estimates:⁴²

$$\text{Blood biomass} = 0.07 * X_{14t}^{0.84}$$

$$\text{Liver biomass} = 0.02 * X_{14t}^{0.7}$$

$$\text{Bone biomass} = 0.05 * X_{14t}$$

Finally, the total biomass of muscle tissue available to the population on a yearly basis is estimated at 45% of the total mass of all ruminants in the herd adjusted for the fraction which comes from outside sources (I_{181t}).^{1,2}

XII. PERIPHERAL FLOW THROUGH FOREST STRUCTURE AND FOREST MANAGEMENT MODULES

The development of strategies for estimating the flow of biomass and TRU through a forest ecosystem has been given special consideration in the overall model^{4,5} because of the importance of these ecosystems in the study area. The forest structure module does not affect the flow of biomass, but partitions it into subcompartments with differing attributes. Likewise, TRU flow is not affected in a direct sense, and is also partitioned concomitantly with biomass. Access to the forest management module will affect flow and is functionally dependent on the previous module as a driver. In addition, other attributes of a forest ecosystem are outputs of this module such as crown cover, bole diameter distribution, age estimates, and the TRU specific activity in the wood of trees with different diameters.

Most of the strategies employed in the model are hypothetical, and are the result of module generalizations from specific attributes of a Ponderosa Pine type forest which was used in its development.^{4,5,28,48} The present module is the result of an earlier development³ which began by comparing diameter class evolution as a dynamic modified log-normal distribution⁴⁴ based on total volume of a stand in a given area. As a result of tuning of such a model, results were obtained which gave reasonable output, but it was not sensitive or capable of coping with perturbations of the type required for forest management operations; nor for negative biomass excursions from one year to the next. A later development⁵ attempted to couple a log-normal type generator for initial diameter classes, and to interphase the generator with a compartmental model strategy that would yield results similar to a modified log-normal distribution generator applied to the whole stand volume. Subsequent development led to complete replacement of distribution generators for all classes, and to the refinement of the compartmental approach which yields satisfactory forest structure operation for Ponderosa Pine⁴⁵ and Pinon woodland forest.⁴⁶

A diagram of the forest structure module is presented in Fig. 11 and is a modification of an earlier version.⁵ The flow of biomass into the module is controlled by the gate I_{10} for a specific plant; where the following condition must be satisfied for access:

$$L_{101} \leq 733(I_{1321}/2) * (1 - 0.5 * I_{471}) = I_{1331} \quad (\text{App. B, No. 2})$$

where (I_{1331}) is an estimate of biomass density required before diameters larger than 3 diameter units can be expected. The latter is either a virtual or a real estimate of current biomass for a given plant type. Two virtual estimates are formed:

$$I_{1341} - 0.142 * I_{271} * C_{291} * (1 - I_{471}/2)/(I_{371} * I_{361}) - I_{1351} \quad (\text{App. B, No. 84})$$

where

$$I_{1351} = 0.142 * I_{271} * C_{291} * (1 - I_{471}/2)/(I_{371} * I_{361}) \quad (\text{App. B, No. 85})$$

for the previous year; it is recalculated for the current year to compare with (L_{101}) as described for gating into the module. The virtual volume estimates allow diameter classes to have differential diameter growth rates for trees with different taper coefficients. The taper coefficient for Pinon Pine and Ponderosa Pine have been estimated as:

$$C_{29_0} = 0.5/0.2 = 2.5; C_{29_0} = 0.41/0.3 = 1.36$$

Fig. 11.
Biomass and TRU flow in forest structure module.

where

(0.51, 0.41) = dry wood density, (0.2, 0.3) = simple curvilinear regression coefficients for estimating the mass of a tree from the bole diameter for Piñon⁴⁶ and for Ponderosa Pine as described later in this report. Taper coefficients for other tree and shrub types are unverified estimates since regression coefficients are not available. Also, if either succession or niche competition is accessed, the virtual estimates allow virtual tree growth, although at reduced densities as the case may be. The real volume of the stand is estimated as:

$$I_{1861} = 0.142 * I_{271}$$

where

$$I_{1861} = \text{wood volume of stand, ft}^3$$

and

$$I_{271} = \text{biomass density of stand, g/m}^2 \text{ above ground,}$$

The virtual volume of the smallest diameter class ($0 - I_{1821}$, $1 \leq 22$) or the regenerative class is a function of total above ground biomass of the stand:

$$\begin{aligned} X_{20_1} &= I_{1881} * \text{EXP}(-1/C_{271}) * (I_{1881} - I_{1831}) & X_{20_1} > I_{187k} \\ &= 0.0 & X_{20_1} \leq I_{187k} \end{aligned} \quad (\text{App. B, No. 6})$$

where

$1 \leq k \leq 60$, and

$$\begin{aligned} I_{187k} &= I_{144k} * 0.3 & k &= 1 \\ I_{187k} &= I_{144k} * 77.3/I_{1881} & 1 < k \leq 60 \end{aligned} \quad (\text{App. B, No. 86})$$

This class regenerates a forest structure at low biomass densities, and gradually declines in volume and importance as biomass density accumulates; or until another regenerative event is simulated (forest fire, harvesting, etc.) which acts to lower the above ground biomass density. The regenerative class ($k=1$) is directly coupled to the succeeding diameter class:

$$I_{182_2} = k * C_{881}, k=2 \quad (\text{App. B, No. 83})$$

as are all other diameter classes ($k \leq 60$) to each other. This allows proper coupling of the regenerative class volume ($k=1$) to the second volume class ($k=2$):

$$X_{20_2} = I_{1881} - X_{20_1} \quad (\text{App. B, No. 7})$$

Succeeding intraclass transports depend on competition factors acquired by different diameter classes:

- 1) bole diameter area
- 2) crown diameter area
- 3) number of trees in class

A competition factor is estimated as follows:

$$I_{1881} = I_{140k} * (I_{1891} * I_{1411} + C_{291}/2)^2 * (I_{1891})^2 \quad (\text{App. B, No. 87})$$

This factor is used to partition biomass into smaller volume parcels which are used as allocation flows:

$$I_{142k} = I_{1841} * I_{188k} / \sum_{k=1}^n I_{188k}, \quad 2 \leq n \leq 60 \quad (\text{App. B, No. 89})$$

These parcels are then used to simulate interflow and intraflow estimates between diameter classes above the first. The intraflow strategy is modeled to make the parcel generated by the previous class diameter dependent on net wood production:

$$\begin{aligned}
F(4 \cdot 5, 20k) &= I_{143k-1} + I_{143k} * (I_{133k-1} - I_{133k}) / (I_{133k} + I_{133k-1}), \quad I_{1341} > 0.0 \\
&= -I_{143k}, \quad I_{133k} \leq 0.0, I_{1341} > 0.0 \\
&= I_{1341} * (X_{20k} / I_{1351}) * \sum_{k=2}^n I_{133k} - I_{133k} / \sum_{k=2}^n I_{133k}, \quad I_{1341} \leq 0.0 \quad (\text{App. A, No. 62})
\end{aligned}$$

The three processes describe intraflow as a transport from a previous class if net production is positive. However, if net production is negative, a net transport of wood out of a class is modeled if the previous class is empty; otherwise a decrease inversely proportional to the competition factor (I_{133}) is established.

Interclass transport occurs only if net wood production is positive:

$$F(20k, 20k + 1) = I_{1431} * (I_{133k-1}) / (I_{133k} + I_{133k-1}), \quad 2 \leq k \leq 60. \quad (\text{App. A, No. 63})$$

This flow is of either sign and dependent on relative values of two succeeding competition factors. A flow of this type must be adjusted for materials balance to be described later in this report.

Mortality flows are made dependent on competition factors, total plant crown cover, and wood turnover rate:

$$\begin{aligned}
F(20k, P) &= X_{20k} * I_{471} \left/ \left(\left(C_{271} * \left(\sum_{k=1}^n I_{133k} \right) - I_{133k} \right) / \sum_{k=1}^n I_{133k} \right) \right., \\
2 \leq n \leq 60 & \quad (\text{App. A, No. 64})
\end{aligned}$$

This flow is adjusted for materials balance as must be the condition:

$$\begin{aligned}
X_{20k} &= X_{20k} \quad I_{137k} > I_{144k} * 77.3 / I_{1361} \\
&= 0 \quad I_{1371} \leq I_{144k} * 77.3 / I_{1361} \quad (\text{App. A, No. 65})
\end{aligned}$$

which does not allow a new diameter class to be created until an estimated minimum wood volume has been attained. The volume increment difference is estimated as:

$$I_{1431} = I_{1361} - \sum_{k=1}^n X_{20k} \quad (\text{App. B, No. 90})$$

The number of trees per acre is estimated as:

$$X_{131} = X_{20k} / I_{144k} \quad (\text{App. A, No. 66})$$

The adjusted flow into each diameter class ($k > 1$) is estimated as:

$$F(P, 20k) = I_{1431} * I_{138j} / \sum_{k=2}^n I_{138k} \quad I_{1431} > 0.0 \quad (\text{App. A, No. 67})$$

$$= I_{1431} * (1/I_{138k}) / \sum_{k=2}^n 1/I_{138k} \quad I_{1431} \leq 0.0$$

The final adjustment on volume for all classes is:

$$X_{20k} = X_{20k} * I_{138j} / I_{1381} \quad (\text{App. B, No. 8})$$

The number of trees/acre in each diameter class is determined first by estimating the volume of a tree in a given diameter class:

$$I_{144k} = 0.3 * 0.035 * (I_{1451} / C_{291}) * (2 * 24 * 2.54)^2 \quad k = 1$$

$$= (0.035) * (I_{1451} / C_{291}) * [(k * (I_{1321} - 1/2))^2 + (k * (I_{1321} + 1/2))^2] / 2 \quad 2 \leq k \leq 60$$

(App. B, No. 91)

Volume estimates of this type have been obtained for pinon and juniper,⁴⁶ and for ponderosa pine during the course of this research. They are based on curvilinear regression analysis of tree dry weight versus bole diameter.

Weight (kg) = $b_1 D^2$, where b_1 = regression coefficient, and D = bole diameter in cm.

More information of this type is required for other trees included within the model. The number of trees/acre with each class diameter is estimated as:

$$I_{140k} = X_{20k} / I_{144k}$$

The flow of TRU to a given diameter class is modeled after two events:

- 1) addition of TRU during current year
- 2) loss or gain of TRU through volume increment

The addition of TRU during the current year is estimated as:

$$F(5.4, 20k) = | I_{1341} | * I_{1441} * (I_{1381} / I_{1331}) \quad (\text{App. A, No. 68})$$

which allows activity to enter or leave a diameter class during positive and negative excursions of wood production.

Further additions or removal of TRU from a diameter class depends on net wood production:

$$F(P, 20k) = (I_{1471} / 0.142) * (X_{20k})_p / (X_{20k} / 0.142) \quad I_{1471} > 0.0 \quad (\text{App. A, No. 69})$$

$$F(20k,P) = (I_{1471}/0.142) * (X_{20k})_p / (X_{20k}/0.142) \quad I_{1471} \leq 0.0 \quad (\text{App. A, No. 70})$$

where (p) indicates TRU material.

All additions described are subjected to materials balance as the flow criteria applied are proportional but not equitable to total activity in the stand. Hence, the total activity of each diameter class is adjusted:

$$X_{20k} = X_{20k} * (I_{1481} / (X_8 + X_4))$$

where

$$I_{1481} = \sum_{k=1}^n X_{20k} \quad (\text{App. B, No. 92})$$

which represents virtual total activity of the stand prior to adjustment. The specific activity of each diameter class:

$$I_{180k} = (X_{20k})_p / (X_{20k}/0.142) \quad (\text{App. B, No. 93})$$

where (p) refers to TRU pool material. Finally, each time a succeeding diameter class is created the specific activity is set to that of the previous class:

$$I_{180k} = I_{180k-1} \quad (\text{App. B, No. 94})$$

In addition to the flows described above, other attributes of the forest structure are processed in this module:² crown cover, basal area coverage, geometric mean age—etc. Also, the number of simulated years marking the creation of a new diameter class, the interval between formation of a new class and creation of the succeeding one, and an estimate of average age based on these criteria are part of the module; they are described elsewhere.²

Access to the forest management module, unlike the forest structure module, does affect both biomass and TRU through user selected events. However, the module is actually an extension of the latter, and is functionally dependent on it. Selected harvesting schemes,^{2,26} have been included:

- 1) selected diameter cuts
- 2) "Reverse-J" cut
- 3) forest fire event

A forest fire event also includes the option of complete or partial removal of timber. About 1/10 of the TRU in the wood is assumed to enter the above ground humus compartment containing TRU (X_9). Most of the operations involved in the module are "bookkeeping" operations which augment or decrease pool materials; they are described in the code documentation portion of this report.²

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APPENDIX A

FLOWS

I. FIGURE 6 FLOWS

$$1. F(P,1) = F(P,2) = F(D_1, I_1, S_1, I_6, S_2, S_3, I_4)$$

$F(P,1)$ = transport of water from precipitation events to soil

$F(P,2)$ = transport of water from snow to soil

D_1 = annual precipitation, inches

I_1 = Jan. through Dec. monthly precipitation fractions

S_1 = random number drawn from a normal distribution ($m = 0, \sigma = 1$)

I_6 = coefficient of variation for precipitation/event of reference site

S_2 = integer value of product of random no. and no. of days in a month

S_3 = random number drawn from a normal distribution ($m = 0, \sigma = 1$)

I_4 = total rainfall events/month totaling more than 0.1"

$$2. F(P,1) = D_1 I_1 S_1 (1 + I_6 S_3)$$

$$I_6 = |S_2|$$

$$= 0$$

$$I_6 = |S_2|$$

$F(P,1)$ = transport of water from precipitation events to soil

D_1 = annual precipitation, inches

I_1 = Jan. through Dec. monthly precipitation fractions

S_1 = random number drawn from a normal distribution ($m = 0, \sigma = 1$)

I_6 = coefficient of variation for precipitation/event of reference site

S_3 = random number drawn from a normal distribution ($m = 0, \sigma = 1$)

S_2 = integer value of product of random no. and no. of days in a month

I_6 = day number

$$3. F(2,1) = C_1 * X_2$$

$F(2,1)$ = transport of water from snow to soil

C_1 = snow melt coefficient, $1.128 \text{ mm } ^\circ\text{C}^{-1}$

X_2 = precipitation as snow, mm

$$4. F(1,P) = X_1 + P - I_{16}$$

$$X_1 + P > I_{16}$$

$$= 0$$

$$X_1 + P < I_{16}$$

$F(1,P)$ = transport of moisture from soil due to runoff

X_1 = current value of soil moisture availability

I_{16} = holding capacity of soil, % H_2O

$$\begin{aligned}
5. \quad F(1,3 \cdot 4 \cdot 5) &= I_{18} & X_1 &> I_{18} \\
&= I_{18} * X_1 / I_{18} & I_{17} &\leq X_1 \leq I_{18} \\
&= 0 & X_1 &< I_{17}
\end{aligned}$$

$F(1,3 \cdot 4 \cdot 5)$ = transport of moisture to roots, stems, and leaves from soil, mm
 I_{18} = potential evapotranspiration rate
 X_1 = current value of soil moisture availability
 I_{18} = field capacity of soil, % H_2O
 I_{17} = wilting point of soil, % H_2O

$$6. \quad F(P,1) = (1 - I_9) * I_{20}$$

$F(P,1)$ = "virtual flow of moisture from lower soil depths (>250 mm)
 I_9 = soil evapotranspiration adjustment for soil depth
 I_{20} = adjusted evapotranspiration rate, mm/250 mm

II. FIGURE 7 FLOWS

$$\begin{aligned}
7. \quad F(P,5) &= X_5 * I_{21} * I_{22} * I_{23} & L_2 &= 1 \\
&= 0 & L_2 &= 0
\end{aligned}$$

$F(P,5)$ = potential gross photosynthesis, g/m^2
 X_5 = needle or leaf biomass, kg/m^2
 I_{21} = effect of temperature, $^{\circ}C$, on photosynthesis for plant
 I_{22} = effect of soil moisture on photosynthesis for plant
 I_{23} = maximum photosynthetic efficiency (grams $(CH_2O)/m^2$ per gram photosynthetic biomass/ m^2)
 L_2 = (0 or 1), determines whether photosynthesis is occurring

$$\begin{aligned}
8. \quad F(3,P) + F(4,P) + F(5,P) &= (X_5 + C_{11} * X_5) * C_{12} * EXP(C_{13} * D_2) * C_{14} & L_3 &= 1 \\
&= 0 & L_3 &= 0
\end{aligned}$$

$F(3,P) + F(4,P) + F(5,P)$ = total plant respiration, g/m^2
 X_5 = needle or leaf biomass, g/m^2
 C_{11} = respiratory maintenance component, see App. C
 C_{12} = respiratory effect 1, see App. C

C_{13} = respiratory effect 2, see App. C
 D_2 = daily temperature, °C
 C_{14} = respiratory effect 3, see App. C
 L_3 = (0 or 1) determines whether respiration is occurring(1)

$$9. F(3,P) = 0.3 * X_3 * C_{12} * EXP(C_{13} * D_2) * C_{14}$$

$F(3,P)$ = root respiration, g/m²

X_3 = g/m² live root biomass

C_{12} = respiratory effect 1, see App. C

C_{13} = respiratory effect 2, see App. C

D_2 = daily temperature, °C

C_{14} = respiratory effect 3, see App. C

$$10. F(4,P) = \text{respiration of stems, g/m}^2$$

$$11. F(5,P) = \text{respiration of leaves, g/m}^2$$

$$12. F(P,5) = \text{potential gross photosynthesis, g/m}^2$$

$$13. F(4,3) = C_{18} * I_{35} \quad I_{35} \geq 0$$

$$= I_{35} * (X_3 / (X_3 + I_{27})) \quad I_{35} < 0$$

$F(4,3)$ = transport of photosynthate to roots from above ground parts, g/m²

C_{18} = fraction of photosynthate transferred to roots (RTRANS), see App. C

I_{35} = g/cm², biomass net production on a given day

X_3 = needle or leaf biomass, g/m²

$$14. F(4,7) + F(5,7)$$

$$= 0.693 * X_6 / 730 + I_{27} * I_{38}$$

$$= I_{38} * I_{27}$$

$$= I_{38} * I_{27} + X_6$$

$$= 0.005 * I_{27}$$

$$= I_{27} * (C_{20} * (D_2 - C_{21}) + C_{22}) * 0.05$$

$$= I_{27} * (C_{23} - C_{24} * D_2) * 0.05$$

$$= 0.1 * I_{27}$$

$$O_6 = 0, L_5 = 0, L_4 = 1$$

$$O_6 = 0, L_5 = 0, L_4 = 0$$

$$O_6 = 0, L_5 = 0, L_4 = 0, D_2 = I_{22}$$

$$O_6 = 0, L_5 = 1, L_4 = 0, C_{23} \leq D_2 \leq C_{21}$$

$$O_6 = 0, L_5 = 1, L_4 = 0, D_2 > C_{21}$$

$$O_6 = 0, L_5 = 1, L_4 = 0, D_2 < C_{23}$$

$$O_6 = 1, L_5 = 1, L_4 = 0, I_5 = I_{39}$$

$$F(4,7) + F(5,7) = \text{combined flow of stem mortality and leaf drop, g/m}^2$$

X_6 = needle or leaf biomass, g/m²

I_{27} = g/m² live above ground biomass

I_{38} = factor to determine mortality of certain plant types

D_2 = daily temperature, °C

C_{20} = mortality factor 1, see App. C

C_{21} = mortality temperature effect, °C, see App. C

C_{22} = mortality factor 2, see App. C

C_{23} = mortality factor 3, see App. C

C_{24} = mortality factor 4, see App. C

O_6 = determines whether irrigation schedule for plant type will be part of input

L_5 = distinguishes woody plants(0) from herb types(1)
 L_4 = determines whether leaf fall occurs at the end of frost-free period (0) or if evergreen(1)
 I_{32} = end of frost-free period, day number
 C_{26} = mortality temperature factor, lower, °C, see App. C
 I_5 = day number
 I_{39} = harvesting schedule, day of year

$$\begin{aligned}
 15. \quad F(3,6) &= (F(4,7) + F(5,7)) * (X_3/I_{27}) && \text{plants (1,2,4,5,6,9,10,12,14,15,16,20,21)} \\
 &= (F(4,7) + F(5,7)) * (X_3/I_{27}) + I_{38} * X_3 && \text{plants(7,19)} \\
 &= X_3 * I_{38} && \text{plants (3,8,11,13,18)} \\
 &= X_3 && \text{plants (1,2,12), } I_5 = I_{39}
 \end{aligned}$$

$F(3,6)$ = mortality losses, roots to dead roots, g/m²
 X_3 = g/m² live root biomass
 I_{27} = g/m² live above ground biomass
 I_{38} = factor to determine mortality factor of certain plant types
 I_5 = day number
 I_{39} = harvesting schedule, day of year
 $F(4,7) + F(5,7)$ = combined flow of stem mortality and leaf drop

$$16. \quad F(7,9) = I_{40} * I_{41} * X_7$$

$F(7,9)$ = mortality losses from dead leaf stem to leaf stem litter, g/m²
 I_{40} = dead biomass temperature decay factor
 I_{41} = dead biomass soil moisture decay factor
 X_7 = g/m² dead standing biomass for specific plant

$$17. \quad F(6,8) = I_{40} * I_{41} * X_6$$

$F(6,8)$ = mortality losses from dead roots to root litter, g/m²
 I_{40} = dead biomass temperature decay factor
 I_{41} = dead biomass soil moisture decay factor
 X_6 = g/m² dead root biomass

$$18. \quad F(8,P) = X_8 * 0.3 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14}$$

$F(8,P)$ = root decomposition rate, g/m²
 X_8 = g/m² of root litter-humus
 C_{12} = respiratory effect 1, see App. C
 C_{13} = respiratory effect 2, see App. C
 D_2 = daily temperature, °C
 C_{14} = respiratory effect 3, see App. C

$$19. F(9,P) = X_9 * 0.3 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14}$$

$F(9,P)$ = above ground humus decomposition rate, g/m^2

X_9 = g/m^2 above ground litter-humus

C_{12} = respiratory effect, see App. C

C_{13} = respiratory effect 2, see App. C

D_2 = daily temperature, $^{\circ}\text{C}$

C_{14} = respiratory effect 3, App. C

III. FIGURE 8 FLOWS

$$20. F(P,12) = I_{43} \quad L_6 > 0$$

$$I_{44} \quad L_7 > 0$$

$$I_{45} \quad O_4 = 1, O_3 > 1, O_4 = 3$$

$F(P,12)$ = flow of TRU to atmosphere, activity/ m^3

I_{43} = amount of atmospheric activity/ m^3 on a given day for given year (64 day event possible, 16 years possible)

I_{44} = function Airac, see App. E

I_{45} = activity/ m^3 from fire increment to total air activity

L_6 = total number of years of an acute event

L_7 = year of initial contaminating chronic event

O_3 = selector for specific plants to be simulated

O_4 = number of managed cuttings or events simulated

$$21. F(12,P) = X_{12} = F(P,12)$$

X_{12} = activity/ m^3 including fire increment to total air activity if simulated

$$22. F(10,12) = (3 \times 10^4) * (I_{42} * X_{10}) \quad I_{48} = 0$$

$$= 0 \quad I_{48} > 0$$

$F(10,12)$ = flow of TRU from soil surface (upper 2 cm) to atmosphere, activity/ m^3

I_{42} = resuspension factor, day^{-1}

X_{10} = soil activity, activity/gram dry weight in a given soil horizon

I_{48} = daily precipitation events

$$23. F(11,12) = I_{42} * I_{11} \quad I_{48} = 0$$

$$= 0 \quad I_{48} > 0$$

$F(11,12)$ = resuspension of TRU from plant surfaces, activity/ m^3

I_{42} = resuspension factor, day^{-1}

X_{11} = plant surface activity, activity/ m^2

I_{48} = daily precipitation events

$$24. F(12,10) = 0.0021 * X_{12}/3 \times 10^4 \quad I_{48} = 0$$

$$= 0.7 * X_{12} * (1 - \text{EXP}(-0.6518 * I_{48}))/ (3 \times 10^4) \quad I_{48} > 0$$

F(12,10) = depositional flow of TRU from atmosphere to soil, activity/m²
 X₁₂ = activity/m³ including fire increment to total air activity if simulated
 I₄₈ = daily precipitation events

$$25. F(12,11) = 0.0021 * X_{12} * I_{49} * 0.67 \quad I_{48} = 0$$

$$= 0.7 * X_{12} * (1 - \text{EXP}(-0.6518 * I_{48})) * I_{49} \quad I_{48} > 0$$

F(12,11) = deposition of particulates containing TRU on plant surfaces, activity/m²
 X₁₂ = activity/m³ including fire increment to total air activity when simulated
 I₄₈ = daily precipitation events, mm
 I₄₉ = leaf area index, m²/m², for specific plant category

$$26. F(11,10) = (0.693/30) * X_{11}/3 \times 10^4 \quad I_{48} = 0$$

$$= 0.3 * X_{11} * (1 - \text{EXP}(-0.6518 * I_{48}))/3 \times 10^4 \quad I_{48} > 0$$

F(11,10) = flow of TRU from plant to soil surfaces or washoff, activity/m²
 X₁₁ = activity/m² on leaf surface of specific plant
 I₄₈ = daily precipitation events

$$27. F(9,12) = I_{42} * X_9 \quad I_{48} = 0$$

$$= 0 \quad I_{48} > 0$$

F(9,12) = flow of fine litter particles containing TRU to resuspendable material, activity/m²
 I₄₂ = resuspension factor, day⁻¹
 X₉ = activity/m² above ground litter-humus
 I₄₈ = daily precipitation events

$$28. F(9,10) = 0.3 * X_9 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14}/3 \times 10^4$$

F(9,10) = flow of TRU from fine litter-humus compartment into soil surface, act/m²
 X₉ = activity/m² above ground litter-humus
 C₁₂ = respiratory effect 1, see App. C
 C₁₃ = respiratory effect 2, see App. C
 D₂ = daily temperature, °C
 C₁₄ = respiratory effect 3, see App. C

$$29. F(10,1) = (0.693/700) * X_{10} * (3 \times 10^4/3.75 \times 10^5) \quad I_{48} = 0$$

$$= 0.01 \times (1 - \text{EXP}(-0.6518 * I_{48})) * X_{10} * (3 \times 10^4/3.75 \times 10^5) \quad I_{48} > 0$$

F(10,1) = flow of TRU from the resuspendable horizon to the next 250 mm soil horizon below, activity/m²
 X₁₀ = soil activity, activity/gram dry weight in given soil horizon
 I₄₈ = daily precipitation events

$$30. F(1,3) = \sum_{i=1}^{I_{54}} I_{51,1} * I_{52,1} * I_{53,1} * X_5 * I_{20} * 10^9 \quad i \leq I_{55}$$

$$= 0 \quad i > I_{55}$$

F(1,3) = flow of TRU to roots from soil, activity/m²

I₅₄ = number of soil horizons in 250 mm intervals

I₅₁ = soil activity, activity/gram dry weight in given soil horizon

I₅₂ = uptake coefficient for a radionuclide in given soil horizon

I₅₃ = root fraction in given soil horizon

X₅ = needle or leaf biomass, g/m²

I₂₀ = adjusted evapotranspiration rate, mm/250 mm

I₅₅ = root penetration, mm, as a function of total days elapsed

$$31. F(3,6) = X_3 * (F(3,6)/X_6)_b$$

F(3,6) = mortality flow of TRU from roots to dead roots, activity/m²

X₃ = activity/m² live root biomass

X₆ = activity/m² dead root biomass

b⁶ = biomass flow

$$32. F(6,8) = X_6 * I_{40} * I_{41}$$

F(6,8) = flow of TRU from dead roots to humus, activity/m²

X₆ = activity/m² dead root biomass

I₄₀ = dead biomass temperature decay factor

I₄₁ = dead biomass soil moisture decay factor

$$33. F(8,X_{11}) = X_6 * I_{52,1} * 3 * C_{12} * \text{EXP}(C_{13} * D_2) * C_{14}$$

F(8,X₁₁) = flow of TRU from root humus to soil, activity/m²

X₆ = activity/m² root litter-humus

I₅₂ = uptake coefficient for a radionuclide in a given soil horizon

C₁₂ = respiratory effect 1, see App. C

C₁₃ = respiratory effect 2, see App. C

D₂ = daily temperature, °C

C₁₄ = respiratory effect 3, see App. C

I₅₄ = number of soil horizons in 250 mm intervals

I₅₅ = root penetration, mm, as a function of total days elapsed

$$34. F(3,4.5) = X_3 * I_{55} * I_{27}/I_{59}$$

F(3,4.5) = flow of TRU from the roots into above ground parts

X₃ = activity/m² live root biomass

I₂₇ = g/m² live above ground biomass

I₅₅ = biomass transpiration coefficient, day⁻¹

I₅₉ = g/m², above ground biomass + g/m² live root biomass for specific plant

$$35. F(4.5,3) = (X_4 + X_5) I_{58} * (I_{59} - I_{27})/I_{59}$$

$F(4.5,3)$ = flow of TRU from above ground as a result of mortality losses

$X_4 + X_5$ = activity/m² live above ground biomass

I_{27} = g/m³ live above ground biomass

I_{58} = biomass transpiration coefficient, day⁻¹

I_{59} = g/m², above ground biomass + g/m² live root biomass

$$36. F(4,7) + F(5,7) = (X_4 + X_5) + ((F(4,7) + F(5,7))/I_{27})_b$$

$F(4,7) + F(5,7)$ = flow of TRU from above ground parts as a result of mortality losses

$X_4 + X_5$ = activity/m² live above ground biomass

I_{27} = g/m² live above ground biomass

b = biomass flow processes

$$37. F(7,9) = X_7 * I_{40} * I_{41}$$

$F(7,9)$ = flow of TRU from litter to humus, activity/m²

X_7 = activity/m² dead standing biomass

I_{40} = dead biomass temperature decay factor

I_{41} = dead biomass soil moisture decay factor

$$38. \left. \begin{array}{l} \text{a) } F(4,7) + F(5,7) = 0.1 * I_{27} \\ \text{b) } F(3,6) = X_3 \\ \text{c) } I_{27} = 1.0 \\ \text{d) } X_3 = 1.0 \\ \text{e) } F(P,4.5) = 0 \\ \text{f) } F(4,7) + F(5,7) = 0 \\ \text{g) } I_{27} = 20.0 \\ \quad X_7 = X_7 * (20/I_{27}) \end{array} \right\} \begin{array}{l} k = 2; I_5 = I_{62,1} \\ \\ \\ \\ \\ \\ I_5 = I_{62,k}; 2 \leq k \leq 8; I_{27} > 20.0 \end{array}$$

$F(4,7) + F(5,7)$ = flow of TRU from above ground parts as a result of mortality losses, activity/m²

I_{27} = g/m² live above ground biomass

$F(3,6)$ = mortality losses roots to dead roots

X_3 = g/m² live root biomass

I_5 = day number

I_{62} = harvesting schedules, day of year

$F(P,4.5)$ = gross photosynthesis for irrigated crop, g/m²

I_{65} = irrigation schedules, day of year, when water is applied

I_{64} = harvesting schedules, day of year

X_7 = g/m² dead standing biomass

k = harvesting schedule index, $2 \leq k \leq 8$

IV. FIGURE 10 FLOWS

$$39. F(P,13) = I_{81} = (I_{104K,1} - I_{110,K,1}) * (1.0 - 0.3 * I_{82,1})$$

$F(P,13)$ = amount of forage consumed by an animal unit on a given day, kg/day

I_{81} = ingestion rate, kg/day

I_{104} = rumen capacity, kg, for given age category of specific animal category

I_{110} = rumen fill, kg, for kth population age group, lth animal category

$I_{82,1}$ = weighted average % nitrogen content in ingesta of lth animal group

$$40. F(13,17) = I_{105} = (1 - I_{831}) * 0.45 + I_{831} * 0.7$$

$F(13,17)$ = digestible portion of intake, kg/day

I_{105} = digestible fraction of ingested forage

I_{83} = cumulative green biomass uptake for kth food preference category, kg

$$41. F(13,16) = I_{107} = I_{105} * I_{153}$$

$F(13,16)$ = energy derived from the digestible fraction, kcal/day

I_{107} = microprotein in rumen, grams

I_{105} = energy in digestible fraction of intake, kcal

I_{153} = grams/kcal of microprotein in digestible fraction

$$42. F(16,9) = (0.52 * X_{16}) * 0.75$$

$F(16,9)$ = flow of microprotein from the rumen to humus compartment, g/day

X_{16} = microprotein level, grams, in rumen for kth age, lth animal group

$$43. F(13,17) = F(13,17) + I_{1091} * I_{1081} * F(13,17)$$

$F(13,17)$ = net flow of digestible material, kg/day

I_{108} = fermentation digestion rate, fraction/kg

I_{109} = rumen exit rate, fraction/day

$$44. F(17,9) = (I_{1091} * X_{17}) * 0.75$$

$F(17,9)$ = exit of digestible forage portion from the rumen, kg/day

X_{17} = digestible dry matter, kg/day, intake rate for kth population group of lth animal category

I_{108} = rumen exit rate, fraction/day

$$45. F(13,9) = (I_{1091} * X_{13}) * 0.75$$

$F(13,9)$ = flow of undigested food from the rumen, kg/day

I_{109} = rumen exit rate, fraction/day

X_{13} = rumen capacity, kg, for given age of specific animal category

$$\begin{aligned}
46. \quad F(13 \cdot 16 \cdot 17, 14) &= 0.0 & I_{117i} &= \infty \\
&= I_{116i}/4500 & I_{116i} &= 0.0 \\
&= I_{116i}/(I_{117i} * 4300) & 0 \leq I_{117i} &> 1.0
\end{aligned}$$

$F(13 \cdot 16 \cdot 17, 14)$ = actual weight gain by an animal unit on a daily basis, kg/day

I_{116} = net available energy, kcal

I_{117} = fraction of available energy for growth, kcal

$$47. \quad F(4 \cdot 5, 13 \cdot 16 \cdot 17) = I_{83k} * (I_{123i}/I_{72m}) * (I_{80m}/I_{80k}) * I_{121k}$$

$F(4 \cdot 5, 13 \cdot 16 \cdot 17)$ = amount of biomass removed from each plant category by animal unit, g/day

I_{80} = uptake, kg/day, for ith preference category

I_{83} = cumulative green biomass uptake for kth food preference category

I_{72} = available forage, g/m², from all forage sources of ith preference category

I_{121} = fraction of area grazed by an age group of given animal population

I_{123} = g/m² of green and dry standing biomass

$$48. \quad F(7, 13 \cdot 16 \cdot 17) = (1 - I_{83k}) * (I_{123i}/I_{72m}) * (I_{80m}/I_{80k}) * I_{121k}$$

$F(7, 13 \cdot 16 \cdot 17)$ = amount of biomass uptake from dead standing biomass, g/m²

I_{83} = cumulative green biomass uptake for kth food preference category

I_{123} = g/m² of green and dry standing biomass

I_{72} = available forage, g/m², from all forage sources of ith preference category

I_{80} = uptake, kg/day, for ith preference category

I_{121} = fraction of area grazed by an age group of given animal population

$$49. \quad F(4 \cdot 5, 13 \cdot 16 \cdot 17) = (X_4 + X_5) * (F(4 \cdot 5, 13 \cdot 16 \cdot 17))_b / I_{27}$$

$F(4 \cdot 5, 13 \cdot 16 \cdot 17)$ = TRU flow from green biomass into the rumen, activity/day

$F(4 \cdot 5, 13 \cdot 16 \cdot 17)$ = amount of biomass removed from each plant category by animal unit, g/day

$X_4 + X_5$ = activity/m² live above ground biomass

I_{27} = g/m² live above ground biomass

b = biomass flow

$$50. \quad F(7, 13 \cdot 16 \cdot 17) = X_7 * (F(7, 13 \cdot 16 \cdot 17)/X_7)_b$$

$F(7, 13 \cdot 16 \cdot 17)$ = TRU flow from dry biomass to rumen, activity/m²

X_7 = activity/m² of dead standing biomass

b = biomass flow

$$51. F(11,13 \cdot 16 \cdot 17) = X_{11} * [F(7,13 \cdot 16 \cdot 17) + F(4 \cdot 5,13 \cdot 16 \cdot 17)/(I_{27} + X_7)]_b$$

$F(11,13 \cdot 16 \cdot 17)$ = TRU flow from dry biomass surface to rumen, activity/day

$F(7,13 \cdot 16 \cdot 17)$ = flow from dry biomass to rumen, g/m²

$F(4 \cdot 5,13 \cdot 16 \cdot 17)$ = flow from green biomass into the rumen, g/m²

X_{11} = activity/m² on plant surfaces

I_{27} = g/m² live above ground biomass

X_7 = activity/m² of dead standing biomass

b = biomass flow

$$52. F(10,13 \cdot 16 \cdot 17) = I_{128} * C_{32k} * I_{100} * X_{10}$$

$F(10,13 \cdot 16 \cdot 17)$ = flow of TRU from soil into the rumen, activity/day

I_{128} = soil ingestion, grams/day

C_{32} = fraction of population by age(Z), see App. C

I_{100} = number of animal units on range for a given grazing interval

X_{10} = soil activity, activity/gram dry weight in top 2 cm soil horizon

$$53. F(10 \cdot 13 \cdot 16 \cdot 17, 14) = I_{128k} * 0.001 * X_{10}$$

$F(10 \cdot 13 \cdot 16 \cdot 17, 14)$ = flow of TRU from soil sources across rumen wall, activity/day

I_{128} = soil ingestion, g/day

X_{10} = soil activity, activity/gram dry weight in top 2 cm soil horizon

$$54. F(12,18) = 0.15 * X_{12} * I_{128k} - 4.34 \times 10^{-4} * X_{18}$$

$F(12,18)$ = flow of TRU into the lungs from atmosphere, activity/day

X_{12} = activity/m³ including fire increment to total air activity if simulated

I_{128} = inhalation rate, m³/day, for kth population category, lth animal category

X_{18} = accumulated activity entering pulmonary region for kth population category, lth animal category

$$55. F(18 \cdot 16 \cdot 17 \cdot 13, 14) = 1.34 \times 10^{-4} * 0.001 * X_{18}$$

$F(18 \cdot 16 \cdot 17 \cdot 13, 14)$ = flow of TRU from pulmonary region of lungs to the gut and across the rumen wall, activity/day

X_{18} = accumulated activity entering pulmonary region for lth animal category

$$56. F(18,14) = 3.61 \times 10^{-8} * X_{18}$$

$F(18,14)$ = flow of TRU directly across the alveolar membrane, activity/day

X_{18} = accumulated activity entering pulmonary region for lth animal category

$$57. F(12 \cdot 17 \cdot 16 \cdot 13, 14) = I_{128} * X_{12} * 0.35 * 0.001$$

$F(12 \cdot 17 \cdot 16 \cdot 13, 14)$ = flow of TRU across the rumen wall for nonpulmonary deposits, activity/day

I_{128} = inhalation rate, m³/day, for kth population category, lth animal category

X_{12} = activity/m³ including fire increment to total air activity if simulated

$$58. F(5 \cdot 7 \cdot 17 \cdot 16 \cdot 13, 14) = 0.001 * F(10, 13 \cdot 16 \cdot 17)$$

$F(5 \cdot 7 \cdot 17 \cdot 16 \cdot 13, 14)$ = flow of TRU across rumen from consumed forage, activity/day
 $F(10, 13 \cdot 16 \cdot 17)$ = flow of TRU from soil into the rumen, activity/day

$$59. F(13 \cdot 16 \cdot 17, 9) = F(10 \cdot 13 \cdot 16 \cdot 17, 14) + F(18 \cdot 17 \cdot 16 \cdot 13, 14) + F(12 \cdot 17 \cdot 16 \cdot 13, 14)$$

$$+ F(5 \cdot 7 \cdot 17 \cdot 16 \cdot 13, 14) / (0.999 * I_{1221} * C_{34})$$

$F(13 \cdot 16 \cdot 17, 9)$ = TRU flow entering rumen from all sources, activity/day
 $F(10 \cdot 13 \cdot 16 \cdot 17, 14)$ = flow of TRU from soil sources across rumen wall, activity/day
 $F(18 \cdot 17 \cdot 16 \cdot 13, 14)$ = flow of TRU from pulmonary region of lungs to the gut and across the rumen wall, activity/day
 $F(12 \cdot 17 \cdot 16 \cdot 13, 14)$ = flow of TRU across the rumen wall from nonpulmonary deposits
 $F(5 \cdot 7 \cdot 17 \cdot 16 \cdot 13, 14)$ = flow of TRU across rumen from consumed forage, activity/day
 I_{122} = fraction of region grazed by specific animal unit
 C_{34} = area of regional grid (M7) = $3.73 \times 10^8 \text{m}^2$

$$60. P(14, 15) = X_{14} * C_{32k} * 0.001 / (I_{180k} * 0.9) \quad k \geq 3$$

$$= 0 \quad k < 3$$

$F(14, 15)$ = flow of TRU to milk, activity/day
 X_{14} = biomass, kg, for animal classes specified
 C_{32} = fraction of population by age(Z), see App. C
 I_{130} = blood weight (kg) for kth population category, lth animal category

$$61. F(15, P) = 1.0 = \text{flow of TRU from milk out of system, activity/day}$$

$$62. F(4 \cdot 5, 20k) = I_{1421-1} + I_{1421} * (I_{180k-1} - I_{180k}) / I_{180k} + I_{180k-1} \quad I_{1341} > 0.0$$

$$= I_{1421} \quad I_{1341} > 0.0,$$

$$= I_{1341} * (X_{20k} / I_{1801}) * \left[\left(\sum_{k=2}^n I_{180k} \right) - I_{180k} \right] / \sum_{k=2}^n I_{180k} \quad I_{180k} \leq 0.0$$

$$\quad I_{134k} \leq 0.0$$

$F(4 \cdot 5, 20i)$ = intraflow of biomass as a transport to diameter class(k) from net photosynthesis
 I_{142} = growth allocation factor, ft^3
 I_{180} = total advantage factor for ith diameter class for biomass allocation
 I_{184} = growth increment, ft^3/yr , for specific plant in a given year
 X_{20} = volume, ft^3 , of specific plant with diameter (k)
 I_{185} = virtual volume, ft^3 , required for setting radial growth rate of boles

$$63. F(20k, 20k + 1) = I_{142k} * (I_{199k-1} - I_{198k}) / (I_{199k} + I_{198k-1}), \quad 2 \leq k \leq 60$$

$F(20k, 20k + 1)$ = biomass transport from class (k) to class (k+1)

I_{142} = growth allocation factor, ft^3

I_{198} = total advantage factor for kth diameter class for biomass allocation

$$64. F(20k, P) = X_{20k} * I_{47} / \left(\left(C_{271} * \left(\sum_{k=1}^n I_{198k} \right) - I_{198k} \right) / \sum_{k=1}^n I_{198k} \right) \quad 2 \leq n \leq 60$$

$F(20k, P)$ = mortality flow of wood from a diameter class (k), ft^3/day

X_{20} = volume, ft^3 , of specific plant with diameter (k)

I_{47} = fractional crown cover for specific plant

C_{27} = mean average life-span (HF) of plant, years, see App. C

I_{198} = total advantage factor for kth diameter class for biomass allocation

$$65. \begin{aligned} 20k &= 20k & I_{197k} &> I_{144k} * 77.3/I_{1981} \\ &= 0 & I_{197k} &\leq I_{144k} * 77.3/I_{1981} \end{aligned}$$

I_{197} = volume, ft^3 , of specific plant with diameter (k)

I_{144} = volume of tree with diameter (k)

I_{198} = virtual volume, ft^3 , required for setting growth rate of boles

$$66. X_{19k} = X_{20k}/I_{144k}$$

I_{144} = volume of tree with diameter (k)

$$67. F(P, 20k) = I_{1491} * I_{198k} / \sum_{k=2}^n I_{198k} \quad I_{1491} > 0.0$$

$$= I_{1491} * (1/I_{198k}) / \sum_{k=2}^n 1/I_{198k} \quad I_{1491} \leq 0.0$$

$F(P, 20k)$ = adjusted biomass flow into each diameter class ($k > 1$), $ft^3/year$

I_{198} = total advantage factor for ith diameter class for biomass allocation

I_{149} = growth allocation factor, ft^3

$$68. F(5.4, 20k) = | I_{1341} | * I_{1461} * (I_{1981}/I_{1981})$$

$F(5.4, 20k)$ = addition of TRU during current year

I_{134} = growth increment, $ft^3/year$, for specific plant in a given year

I_{198} = virtual stand volume, ft^3 , required for setting growth rate of boles

I_{198} = wood of stand, ft^3

I_{146} = change in specific activity, activity/ m^2 , from one year to the next

$$69. F(P,20k) = (I_{1471}/0.142) * (X_{20k})_p / X_{20k}/0.142) \quad I_{1471} > 0.0$$

F(P,20k) = mortality losses of TRU from class diameter (k)

I_{1471} = change in volume for succeeding years

X_{20k} = volume, ft³, of specific plant with diameter (k)

p = TRU material

$$70. F(20k,P) = (I_{1471}/0.142) * (X_{20k})_p / (X_{20k}/0.142) \quad I_{1471} \leq 0.0$$

F(20k,P) = mortality losses of TRU from class diameter (k)

I_{1471} = change in volume for succeeding years

X_{20k} = volume, ft³, of specific with diameter (k)

p = TRU material

APPENDIX B

EQUATIONS INVOLVING SECONDARY INTERMEDIATE VARIABLES

I. EQUATIONS INVOLVING INTERMEDIATE VARIABLES

$$1. \quad I_3 = C_4 / (1 - \text{EXP}(-C_5 * I_{19}))$$

I_3 = soil evapotranspiration adjustment for soil depth
 C_4 = soil depth adjustment, 0.632
 C_5 = soil depth exponential adjustment, 0.004
 I_{19} = soil depth, mm

$$2. \quad I_{18} = C_2 + C_3 * D_2$$

I_{18} = potential evapotranspiration rate, mm, from top 250 mm soil/day
 C_2 = evapotranspiration intercept, 0.6 mm/day
 C_3 = evapotranspiration proportionality, 0.18 mm/day/°C
 D_2 = daily temperature, °C

$$3. \quad I_{21} = 1 - (D_2 - C_6)^2 / C_7 \quad D_2 > C_6$$

$$= 1 - (D_2 - C_6)^2 / C_8 \quad D_2 \leq C_6$$

I_{21} = effect of temperature (°C) on photosynthesis
 D_2 = daily temperature, °C
 C_6 = optimum growth temperature, °C, see App. C
 C_7 = effect of temperature, above optimum, °C, see App. C
 C_8 = effect of temperature, below optimum, °C, see App. C

$$4. \quad I_{22} = 1 - \text{EXP}(-(C_9 / I_{16} - I_{17})) * (X_1 - I_{17})) + 0.01$$

I_{22} = effect of soil moisture on photosynthesis for plant(l)
 C_9 = effect of soil moisture on photosynthesis, see App. C
 I_{16} = field capacity of soil, % H₂O
 I_{17} = wilting point of soil, % H₂O
 X_1 = current value of soil moisture availability

$$5. \quad I_{23} = C_{10} * D_3$$

I_{23} = maximum photosynthetic efficiency (grams CH₂O/m²/day)
 C_{10} = effect of solar radiation on photosynthesis,² 0.001/Ly/day
 D_3 = solar radiation Ly/day

$$6. \quad I_{27} = (X_4 + X_5)$$

I_{27} = g/m² live above ground biomass

X_4 = g/m² live above ground biomass

X_5 = needle or leaf biomass, g/m²

$$7. \quad I_{28} = \sum_{i=1}^{I_{30}} I_{29i}/I_{30}$$

where

$$I_{291} = I_{291}$$

$$L_5 = 1$$

$$= X_5$$

$$L_5 = 0; X_5 < I_{291}$$

L_5 = distinguishes woody plants(0) from herb types(1)

X_5 = needle or leaf biomass

I_{28} = running average productivity kg/m²/yr

I_{29} = net yearly productivity kg/m²/yr

I_{30} = current year number

$$8. \quad I_{29} = \sum_{i=1}^{365} I_{35i}$$

I_{29} = net yearly productivity, g/m²/yr

I_{35} = g/m², biomass net production on a given day

$$9. \quad I_{33} = (C_{16} - C_{17})/(I_{21} * I_{22})$$

I_{33} = maximum yearly water utilization efficiency for photosynthesis, ml/g CH₂O

I_{21} = effect of temperature (°C) on photosynthesis for plant

I_{22} = effect of soil moisture on photosynthesis for plant

C_{16} = minimum water utilization efficiency, ml/g, see App. C

C_{17} = Hatch-Slack coefficient (PSE), see App. C

$$10. \quad I_{34} = F(P,5) - F(3,P) - F(4,P) - F(5,P)$$

I_{34} = net daily biomass production, g/m²/day

$F(P,5)$ = potential gross photosynthesis, see App. A

$F(3,P)$ = root respiration, g/m², see App. A

$F(4,P)$ = respiration of stems, g/m², see App. A

$F(5,P)$ = respiration of leaves, g/m², see App. A

$$11. \quad I_{35} = I_{34} * I_{36} * I_{37}$$

$$I_{33} * I_{34} \leq I_{20} * 10^0 * I_{36} * I_{37}$$

$$= I_{34} * I_{36}^2 * I_{37}^2 * I_{20} * 10^3 / I_{33} * I_{34}$$

$$I_{33} * I_{34} > I_{20} * 10^3 * I_{36} * I_{37}$$

I_{35} = net biomass production on given day, g/m²
 I_{20} = adjusted evapotranspiration rate, mm/250 mm
 I_{33} = maximum yearly water utilization efficiency for photosynthesis, mL/g CH₂O
 I_{34} = net daily biomass production, g/m²/day
 I_{36} = daily niche competition factor, g/m²
 I_{37} = succession factor

$$12. \quad I_{35} = I_{35} * I_{36} * I_{37}$$

I_{35} = g/m², biomass net production on a given day
 I_{36} = daily niche competition factor, g/m²
 I_{37} = succession factor

$$13. \quad I_{351} = I_{351} * I_{361} * I_{371}$$

I_{351} = g/m², biomass net production on a given day
 I_{361} = daily structural biomass competition factor, g/m²
 I_{371} = succession factor

$$14. \quad I_{36} = I_{36} \quad O_2 = 1.0$$

$$= 1.0 \quad O_2 = 0.0$$

I_{36} = daily structural biomass competition factor, g/m²
 O_2 = determines whether succession module is used(1) or ignored(0)

$$15. \quad I_{361} = [(I_{351}/C_{271} * X_5)] / \sum_{k=1}^n I_{35k} / (C_{27k} * X_{5k}) \quad I_{35} > 0$$

$$= 1.0 \quad I_{35} \leq 0$$

I_{36} = daily structural biomass competition factor, g/m²
 I_{35} = g/m², biomass net production on a given day
 C_{27} = mean average life-span (HF), years, see App. C
 X_5 = needle or leaf biomass kg/m²

$$16. \quad I_{37} = I_{37} \quad O_1 = 1.0$$

$$= 1.0 \quad O_1 = 0.0$$

I_{37} = succession factor calculated on yearly basis
 O_1 = determines which plant groups are to be considered for competition of available land area

$$17. \quad I_{37} = I_{351} / \sum_{k=1}^n I_{35k}$$

I_{37} = succession factor

I_{48} = succession factor

$$13. \quad I_{38} = 2/(365 * C_{27})$$

I_{38} = factor to determine mortality of certain plant types

C_{27} = mean average life-span (HF), years, see App. C

$$19. \quad I_{40} = 0.004 + 0.0032 * D_2$$

I_{40} = dead biomass temperature decay factor

D_2 = daily temperature, °C

$$20. \quad I_{41} = 1.0 + (1/(I_{16} - I_{17})) * (X_1 - I_{17})$$

I_{41} = dead biomass soil moisture decay factor

I_{16} = field capacity of soil, % H_2O

I_{17} = wilting point of soil, % H_2O

X_1 = current value of soil moisture availability

$$21. \quad I_{42} = 2.5 * \text{EXP}(-4.6 * I_{47}) \times 10^{-8}$$

I_{42} = resuspension factor, day^{-1}

I_{47} = fractional crown cover for specific plant

$$22. \quad I_{47} = (1 - \text{EXP}(-1.54 * I_{28}) * I_{41})$$

I_{47} = fractional crown cover for specific plant

I_{28} = running average productivity, $\text{kg/m}^2/\text{yr}$

I_{41} = bole to crown conversion factor

$$23. \quad I_{49} = 0.013 * I_{50}$$

I_{49} = leaf area index m^2/m^2 for specific plant category

I_{50} = edible portion of plants, g/m^2

$$24. \quad I_{50} = X_5 + X_7 \quad \text{a) plants (1,2,3,7,8,11,12,13,18,19)}^1$$

$$= X_5 \quad \text{b) plants (4,5,6,9,10,14,15,16,17,20,21)}$$

I_{50} = edible portion of plants, g/m^2

X_5 = needle or leaf biomass kg/m^2

X_7 = g/m^2 of dead standing biomass

$$25. \quad I_{55} = (1 - \text{EXP}(-0.001 * (I_{46} - 1) * 365 + I_6)) * 9144 \quad C_{27} > 9.0$$

$$= (1 - \text{EXP}(-0.001 * I_6)) * 9144 \quad C_{27} \leq 9.0$$

I_{55} = root penetration, mm, as a function of total days elapsed

I_5 = day number

I_{46} = year number

C_{27} = mean average life-span (HF), years, see App. C

$$26. \quad I_{561} = \sum_{i=1}^{I_{46}} [(I_{271} + X_{51} + X_{51} + X_{71} + X_{51} + X_{51}) / C_{271}] / \sum_{k=1}^{I_{46}} k$$

I_{56} = structural biomass succession factor, g/m²/yr

I_{27} = g/m² live above ground biomass

X_5 = g/m² live root biomass

C_{27} = mean average life-span (HF), years, see App. C

I_{46} = year number

$$27. \quad I_{57} = [\text{EXP}(-0.004 * 250 * (i - 1)) - \text{EXP}(-0.004 * 250i)] / \text{EXP}(-0.004 * I_{54})$$

where

$$(2 \leq i \leq I_{54})$$

I_{57} = root fraction in given soil horizon

I_{54} = number of soil horizons in 250 mm intervals

$$28. \quad I_{55} = \begin{cases} [(I_{50}/(X_5 + C_{11} * X_5)) * [1 - I_{50}/(X_5 + C_{11} * X_5)]]b & I_{27} > 1.0 \\ = 0 & I_{27} \leq 1.0 \end{cases}$$

I_{55} = biomass transpiration coefficient, day⁻¹

X_5 = needle or leaf biomass, g/m²

I_{50} = net daily biomass production shunted to roots, g/m²/day

C_{11} = respiratory maintenance component (ARP), see App. C

I_{27} = live above ground biomass, g/m²

b = biomass flow parameters

$$29. \quad I_{50} = | F(4;3) |$$

$$= (X_5 + C_{11} * X_5)b$$

$$F(4,3) \leq (X_5 + C_{11} * X_5)b - 1.0$$

$$F(4,3) > (X_5 + C_{11} * X_5)b$$

I_{50} = net daily biomass production shunted to roots g/m²/day

X_5 = needle or leaf biomass

C_{11} = respiratory maintenance component (AR), see App. C

$F(4,3)$ = transport of photosynthate to roots from above ground parts, g/m², see Fig. 7
Flows, No. 13

$$30. \quad I_{66i} = I_{74i} * I_{79i} + (1 - I_{74i}) * C_{3i}$$

$$I_{78i} > C_{3i}$$

$$= C_{3i}$$

$$I_{78i} \leq C_{3i}$$

I_{66} = nitrogen content, percentage, of consumed biomass

I_{74} = fraction of diet composed of green biomass for ith plant

I_{79} = initial leaf biomass

I_{78} = nitrogen content, percentage, of standing green biomass

C_{3i} = nitrogen content of dry forage (N3), 0.6%

31. Plant

Rank

$$I_{67i} = I_{47i}$$

1

$$I_{67j} = I_{47j} * (1 - I_{67i})$$

2

$$I_{67i} = I_{47i} * (1 - I_{67i} - I_{67j})$$

3

.

.

.

.

.

.

$$I_{67m} = I_{47m} * (1 - I_{67i} - I_{67j} \dots I_{67m})$$

m

I_{67} = succession factor

I_{47} = fractional crown cover for specific plant

$$32. \quad I_{66i} = (I_{67i}/I_{47i}) * (I_{66i}/I_{69})$$

I_{66} = succession factor

I_{67} = succession ranking factor

I_{47} = fractional crown cover for specific plant

I_{66} = structural biomass succession factor, g/m²/yr (yearly running average)

I_{69} = maximum running average structural biomass succession factor, gm/m²/yr

$$33. \quad I_{71i} = 0.7, i = 1, \quad I_{70j,k} = 1$$

$$= 0.2, i = 2, \quad I_{70j,k} = 2$$

$$= 0.1, i = 3, \quad I_{70j,k} = 3 \quad (1 \leq i \leq 3), (1 \leq j \leq 21), (1 \leq k \leq 4)$$

I_{71} = animal preference fraction for ith food preference category

I_{70} = plants utilized by kth animal category

$$34. \quad I_{71_1} = 0.78, \quad I_{70k,k} = 1$$

$$I_{71_2} = 0.22, \quad I_{70j,k} = 2$$

$$I_{73_3} = 0.0$$

I_{71} = animal preference fraction for ith preference category

I_{73} = total sum of plants utilized for ith food preference category

I_{70} = plants utilized by kth animal category

$$35. \quad I_{71_1} = 1, \quad I_{70j,k} = 1 \quad I_{78_2} = 0.0$$

$$I_{78_3} = 0.0$$

I_{70} = plants utilized by kth animal category
 I_{71} = animal preference fraction for kth preference category
 I_{78} = total sum of plants utilized for ith food preference category

$$36. \quad I_{72i} = \sum_{j=1}^{I_{73i}} [(I_{74j}) * X_{8j} + (1 - I_{74j}) * X_{7j} * X_{8j}/I_{27j}] * I_{78j}$$

I_{72} = available forage g/m² from all forage sources of ith food preference category
 I_{78} = total sum of plants utilized in ith food preference category
 I_{74} = fraction of diet composed of green biomass for plant
 I_{78} = utilization efficiency, fraction of standing forage
 I_{27} = g/m² live above ground biomass
 X_8 = needle or leaf biomass
 X_7 = g/m² of dead standing biomass

$$37. \quad I_{74j} = 3 * X_{8j} / (3 * X_{8j} + X_{7j} * X_{8j}/I_{27j})$$

I_{74} = fraction of diet composed of green biomass for jth plant
 X_8 = needle or leaf biomass, kg/m²
 X_7 = g/m² of dead standing biomass
 I_{27} = g/m² live above ground biomass

$$38. \quad I_{78j} = (1 - \text{EXP}(-0.167(X_{8j} + X_{7j} * X_{8j}/I_{27j})))$$

I_{78} = utilization efficiency, fraction of standing forage for jth plant
 X_8 = needle or leaf biomass, kg/m²
 X_7 = g/m² of dead standing biomass
 I_{27} = g/m² live above ground biomass

$$39. \quad I_{76i} = C_{19} * I_{88}/X_8 \quad I_{76i} > -0.05$$

$$= 0.0 \quad I_{76i} \leq -0.05$$

I_{76} = growth rate, fraction/day, for ith plant
 C_{19} = fraction of photosynthate remaining above ground (STRANS), App. C
 I_{88} = g/m² biomass net production on a given day
 X_8 = needle or leaf biomass, g/m²

$$40. \quad I_{77i} = 3.0 \quad I_{76i} > 0.142$$

$$= (10.9) * I_{76i} + 1.436 \quad I_{76i} \leq 0.142$$

I_{77} = nitrogen content, percentage, of photosynthate for ith plant
 I_{76} = growth rate, fraction/day, for plant category

$$41. \quad I_{78i} = I_{78i} * (I_{78i}/X_{8i}) + (1 - I_{78i}/X_{8i}) * I_{77i}$$

I_{78} = nitrogen content, percentage, of standing green biomass for ith plant

I_{79} = initial leaf biomass

I_{77} = nitrogen content, percentage, of photosynthate

X_8 = needle or leaf biomass, kg/m²

$$42. \quad I_{79i} = I_{79i} \quad I_{79i} > X_{8i}$$

$$= (X_{8i})^2/I_{79i} \quad I_{79i} \leq X_{8i}$$

I_{79} = initial leaf biomass for ith plant

X_8 = needle or leaf biomass, kg/m²

$$43. \quad I_{80i} = I_{71i} * I_{81i}$$

I_{80} = uptake, kg/day, for ith preference category

I_{81} = ingestion rate, kg/day

I_{71} = animal preference fraction for ith preference category

$$44. \quad I_{82k} = \sum_{i=1}^n (I_{80i}/I_{81k}) * \sum_{j=1}^{I_{73}} (I_{181j})/I_{72}$$

I_{82} = nitrogen content of ingested forage, %

I_{80} = uptake, kg/day, for ith preference category

I_{81} = ingestion rate, kg/day

I_{73} = total sum of plants utilized for kth animal category

I_{181} = sum of total nitrogen concentration $\times$ 100 for jth plant in preference group

I_{72} = available forage, g/m², from all forage sources

$$45. \quad I_{82i} = I_{82i} \quad I_{82i} > C_{31}, i > 1$$

$$= 3.0 \quad i = 1$$

$$= C_{31} \quad I_{82i} \leq C_{31}, i > 1$$

I_{82} = nitrogen content of ingested forage, % for ith animal age group

C_{31} = nitrogen content of dry forage, 0.6%

$$46. \quad I_{83k} = \sum_{i=1}^n (I_{80i}/I_{81k}) \sum_{j=1}^{I_{78i}} I_{84j} \quad (1 \leq n \leq 3)$$

I_{83} = cumulative green biomass uptake for kth food preference category

I_{80} = uptake, kg/day, for ith plant in preference category

I_{81} = ingestion rate, kg/day

I_{78} = total sum of plants utilized for ith animal category

I_{84} = available green standing biomass for ith plant in preference category

$$47. I_{64j} = I_{74j} * X_{5j} * I_{75}/I_{72}$$

I_{64} = available green standing biomass for jth preference category

I_{72} = available forage, g/m², from all forage sources

I_{74} = fraction of diet composed of green biomass

I_{75} = utilization efficiency, fraction of standing green forage

X_5 = needle or leaf biomass, kg/m²

$$48. I_{66k} = \sum_{i=1}^n (I_{60i}/I_{61k}) * \sum_{j=1}^{I_{72}} I_{65j}$$

I_{65} = specific activity, activity/gram, for given category consumed daily by kth animal category

I_{60} = uptake, kg/day, for ith plant in preference category

I_{61} = ingestion rate, kg/day

I_{72} = total sum of plants utilized for kth animal category

I_{66} = specific activity of jth plant in preference category, activity/gram

$$49. I_{68j} = I_{75j} * I_{74j} * (X_5 * (X_{4j} + X_{5j})_p + (1 - I_{74j}) * X_7 * X_5 * (X_{7j})_p/I_{27})/I_{72}$$

I_{68} = specific activity of jth preference category, activity/gram

I_{75} = utilization efficiency, fraction of standing green forage

I_{74} = fraction of diet composed of green biomass

X_5 = needle or leaf biomass, kg/m²

X_6 = g/m² live above ground biomass

X_7 = g/m² of dead standing biomass

I_{27} = g/m² live above ground biomass

I_{72} = available forage g/m² from all forage sources

p = TRU pool

$$50. I_{67k} = \sum_{i=1}^n (I_{60i}/I_{61k}) * \sum_{j=1}^{I_{72}} I_{65j}$$

I_{67} = specific activity, activity/gram, on surface of given food category consumed by kth animal category

I_{60} = uptake, kg/day, for ith plant in preference category

I_{61} = ingestion rate, kg/day

I_{72} = total sum of plants utilized

I_{68} = specific activity, activity/gram, for jth plant in food preference category (surface contamination)

$$51. I_{68j} = I_{75j} * I_{74j} * ((X_5 * X_{11j})_p + (1 - I_{74j}) * X_7 * X_5 * (X_{11j})_p/I_{27})/I_{72}$$

I_{68} = specific activity, activity/gram, for jth food preference category (surface contamination)

I_{75} = utilization efficiency, fraction of standing green forage

I_{74} = fraction of diet composed of green biomass

X_6 = needle or leaf biomass, kg/m²
 X_{11} = activity/m² on leaf surface
 X_7 = g/m² of dead standing biomass
 I_{27} = g/m² live above ground biomass
 I_{72} = available forage, g/m², from all forage sources
 p = TRU pool

$$52. \quad I_{99m} = \sum_{i=1}^{I_{73}} (I_{27} - 20 + ((I_{27} - 20)/I_{27}) * X_7) * I_{901} * 4047$$

I_{99} = biomass, grams, available to mth animal category from all plants utilized as supplementary feed during current year
 I_{73} = total sum of plants utilized
 I_{27} = g/m² live above ground biomass
 X_7 = g/m² of dead standing biomass
 I_{90} = number of acres/plant of ith plant utilized

$$53. \quad I_{91m} = \sum_{i=1}^{I_{73}} ((X_{41} + X_{61} + X_{71})p / (I_{271} + X_{71})) * (I_{271} - 20 + ((I_{271} - 20)/I_{271}) * X_{71} * X_{901} * 4047$$

I_{91} = total activity available to mth animal category from irrigated forage
 I_{73} = total sum of plants utilized
 X_4 = g/m² of live above ground biomass of ith plant utilized
 X_6 = needle or leaf biomass, kg/m²
 X_7 = g/m² of dead standing biomass
 I_{27} = g/m² live above ground biomass
 I_{90} = number of acres/plant

$$54. \quad I_{92m} = \sum_{i=1}^{I_{73}} (X_{11i} / (I_{271} + X_{71})) * (I_{271} - 20 + ((I_{271} - 20)/I_{271}) * X_{71} * I_{901} * 4047$$

I_{92} = total surface activity available to mth animal category from irrigated forage
 I_{73} = total sum of plants utilized
 X_{11} = activity/m² on leaf surface of ith plant utilized
 I_{27} = g/m² live above ground biomass
 X_7 = g/m² of dead standing biomass
 I_{90} = number of acres/plant

$$55. \quad I_{96m} = (I_{91m} * I_{99m} + I_{94m} + I_{98m}) / (I_{99m} + I_{98m})$$

I_{96} = total activity available to mth animal category from irrigated forage
 I_{91} = total activity available to animal category from irrigated forage
 I_{99} = biomass, grams, available to animal category from all plants utilized as supplementary feed during current year
 I_{94} = previous year total activity available to animal category from irrigated forage
 I_{98} = previous year biomass, grams, available to animal category as supplementary feed

$$56. I_{97m} = (I_{92m} * I_{99m} + I_{95m}) / (I_{99m} + I_{95m})$$

I_{97} = total surface activity available to mth animal category from irrigated forage

I_{92} = total surface activity available to animal category from irrigated forage

I_{99} = biomass, grams, available to animal category from all plants utilized as supplementary feed during current year

I_{95} = previous year total surface activity available to animal category from irrigated forage

I_{98} = previous year biomass, grams, available to animal category as supplementary feed

$$57. I_{101j} = C_{321} * I_{100j}$$

I_{101} = product of population structure and number of animal units on range

I_{100} = number of animal units on range for jth grazing interval

C_{32} = fraction of population by ith age group (Z), see App. C

$$58. I_{103i} = (C_{331} * I_{102i})^{0.76} \text{ initially, and } I_{103i} = (X_{14i})^{0.76} \text{ thereafter}$$

I_{103} = metabolic biomass (kg) for ith population category

C_{33} = initial weight of beef cattle by age (W), kg, see App. C

I_{102} = animal weights, mature weight ratio

X_{14} = biomass, kg

$$59. I_{104i} = 0.16 * I_{103i}$$

I_{104} = rumen capacity, kg, for a given ith age (yr) category of specific animal category

I_{103} = metabolic biomass, kg

$$60. I_{106} = I_{105} * I_{81} * 4300$$

I_{106} = energy in digestible fraction of intake, kcal

I_{105} = digestible fraction of ingested forage

I_{81} = ingestion rate, kg/day

$$61. I_{108} = (X_{16i} / I_{103i}) * 0.04$$

I_{108} = fermentation digestion rate, fraction/kg

X_{16} = microprotein level, grams, in rumen for ith age

I_{103} = metabolic biomass, kg

$$62. I_{109} = 0.25 + I_{108}$$

$$I_{108} \leq 0.95$$

$$= 0.95$$

$$I_{108} > 0.95$$

I_{109} = rumen exit rate, fraction/day

I_{108} = fermentation digestion rate, fraction/kg

$$63. \quad I_{1101,1} = X_{101} + X_{101} + 0.001 * X_{101}$$

I_{110} = rumen fill, kg, for ith population age group of lth animal category

X_{10} = rumen capacity, kg, the ith age (yr) category

X_{10} = accumulated activity entering pulmonary region for kth population age group, lth animal

X_{10} = microprotein level, grams, in rumen for kth age, lth animal

$$64. \quad I_{111} = 0.747 - 0.15 * (n - 0.6) \quad 0.6 \leq I_{02} \leq 1.8$$

$$= 0.747 \quad I_{02} < 0.6$$

$$= 0.591 \quad I_{02} > 1.8$$

I_{111} = percent of fermented energy as fatty acids

I_{02} = nitrogen content of ingested forage, %

$$65. \quad I_{112} = I_{100} * I_{100} * I_{111}$$

I_{112} = fatty acid energy, kcal

I_{100} = energy in digestible fraction of intake, kcal

I_{100} = fermentation digestion rate, fraction/kg

I_{111} = percent of fermented energy as fatty acids

$$66. \quad I_{113} = [0.25 * [F(13,9) + F(17,9)]] * 4300$$

I_{113} = energy from passed food, kcal

$F(13,9)$ = flow of undigested food from the rumen, kg/day, see App. A

$F(17,9)$ = exit of digestible forage portion from the rumen, kg/day, see App. A

$$67. \quad I_{114} = 0.65 * X_{10} * 4.3 * 0.52$$

I_{114} = energy from microprotein, kcal

X_{10} = microprotein level, grams, in rumen

$$68. \quad I_{115} = I_{112} + I_{113} + I_{114} - 125 * I_{1001}$$

I_{115} = net available energy, kcal

I_{113} = energy from passed good, kcal

I_{114} = energy from microprotein, kcal

I_{112} = fatty acid energy, kcal

I_{100} = metabolic biomass, kg

$$69. \quad I_{1101} = 125 * I_{1001}$$

or

= | I_{115} | for animals on range when respiration exceeds caloric intake

I_{116} = supplementary feed required, grams
 I_{102} = metabolic biomass, kg, for ith population category
 I_{118} = net available energy, kcal

$$\begin{aligned}
 70. \quad I_{1171} &= 0.0 & I_{102} &\geq 1.0 \\
 &= 3.74 + 10.52 * I_{102} & 0.75 &\leq I_{102} < 1.0 \\
 &= 3.74 + 5.26 * I_{102} & 0.5 &\leq I_{102} < 0.75 \\
 &= 1.5 & 0.0 &\leq I_{102} < 0.5
 \end{aligned}$$

I_{117} = fraction of available energy for growth, kcal
 I_{102} = animal weight, mature weight ratio to beef cow

where,

$$71. \quad I_{102} = X_{14} / (C_{33} * I_{1021})$$

X_{14} = weight, kg of kth animal category and age group N
 C_{33} = weight of beef cattle by age (W), kg
 I_{102} = animal weights, mature weight ratio

$$72. \quad I_{1191} = I_{33k} * I_{31k} * 1000 + (1 - I_{33k}) * I_{31k} * 1000$$

I_{119} = total weight of forage consumed, grams
 I_{33} = cumulative green biomass uptake for kth food preference category
 I_{31} = ingestion rate, kg/day

$$73. \quad I_{1191} = I_{1191} / \sum_{j=1}^3 I_{72j}$$

I_{119} = m² grazed by all animal units in a given age group
 I_{118} = total weight of forage consumed, grams
 I_{72} = available forage g/m² from all forage sources of jth preference category

$$74. \quad I_{1301} = I_{1191} * C_{321} * I_{1011}$$

I_{130} = m² grazed by the ith age group of a given animal population
 I_{119} = m² grazed by all animal units
 C_{32} = fraction of population by age(Z), see App. C
 I_{101} = product of population structure and number of animal units on range

$$75. \quad I_{1211} = I_{101}/(I_{1231} * C_{24})$$

I_{121} = fraction of area grazed by the ith age group of a given animal population

I_{101} = product of population structure and number of animal units on range

I_{123} = fraction of region grazed

C_{24} = area of regional grid (M7), $3.73 \times 10^6 \text{m}^2$

$$76. \quad I_{1251} = (I_{741} * X_{51} + (1 - I_{741}) * X_{71} * X_{51}/I_{271}) * I_{751}$$

I_{125} = g/m² of green and dry standing biomass for ith plant

I_{74} = fraction of diet composed of green biomass

X_5 = needle or leaf biomass, kg/m²

X_7 = g/m² dead standing biomass

I_{27} = g/m² live above ground biomass

I_{75} = utilization efficiency, fraction of standing forage

$$77. \quad I_{124k} = (I_{100j}/I_{125k}) * (I_{115k}) * (I_{55k} + I_{57k}) + ((I_{125k} - I_{100j})/I_{125k}) * (I_{115k}) * (I_{51k} + I_{52k}) * I_{125}$$

I_{124} = total activity ingested from forage by kth animal category

I_{100} = number of animal units on range for ith grazing interval

I_{125} = number of animal units

I_{115} = total weight of forage consumed, grams

I_{55} = specific activity, activity/gram, of consumed food

I_{57} = specific activity, activity/gram, on surface of consumed food

I_{115} = supplementary feed required, grams

I_{51} = total activity available from supplementary feed

I_{52} = total surface activity available from supplementary feed

I_{125} = fraction of supplementary feed from study area

$$78. \quad I_{1241} = I_{1241} + | I_{1151}/4.3 | * C_{321} * (I_{51k} + I_{52k}) * I_{125}$$

I_{124} = total activity from ingested forage available to ith age group of kth animal category

I_{115} = net available energy, kcal

C_{32} = fraction of population by age(Z), see App. C

I_{51} = total activity available from supplementary feed

I_{52} = total surface activity available from supplementary feed

I_{125} = fraction of supplementary feed from study area

$$79. \quad I_{1251} = I_{115k} * ((I_{125k} - I_{100j})/I_{125k}) * C_{321}$$

I_{125} = supplementary feed required by ith age category of kth animal type

I_{115} = supplementary feed required, grams

I_{100} = number of animal units on range for jth grazing interval

C_{32} = fraction of population by age(Z), see App. C

$$80. \quad I_{185i} = I_{185i} + I_{100j} * | I_{115i}/4.3 | * C_{33k}$$

I_{125} = supplementary feed increment required by ith age category of kth animal type

I_{100} = number of animal units on range for jth grazing interval

I_{115} = net available energy, kcal

C_{32} = fraction of population by age(Z), see App. C

$$81. \quad I_{128k} = 0$$

$$L_5 = 0$$

$$= (I_{90i}/I_{78k}) * X_{14k} * 3$$

$$L_5 = 1, I_{27} + X_7 < 20$$

$$= (I_{90i}/I_{78k}) * X_{14k} * 20/(I_{27} + X_7)$$

$$L_5 = 1, I_{27} + X_7 \geq 20$$

I_{128} = soil ingestion, grams/day by kth animal category

I_{90} = uptake, kg/day, from ith food preference category

I_{78} = total sum of plants utilized by kth animal category

X_{14} = biomass, kg, of animal unit

I_{27} = g/m² live above ground biomass

X_7 = g/m² of dead standing biomass

L_5 = distinguishes woody plants(0) from herb type(1)

$$82. \quad I_{130i} = (0.07 * X_{14})^{0.94}$$

I_{130i} = blood weight, kg, for kth population category, lth animal category

X_{14} = biomass, kg, of animal unit

$$83. \quad I_{182_1} = k * C_{35i}, \quad k = 2$$

C_{35} = size of diameter class intervals, inches, for ith plant type

I_{182_1} = size of first diameter class, (0 - I_{131_1}) inches,

$$84. \quad I_{184i} = 0.142 * I_{27i} * C_{29i} * (1 - I_{47i}/2)/(I_{37i} * I_{36i}) - I_{135i}$$

I_{184i} = growth increment, ft³/yr, for specific plant in a given year

I_{27} = g/m² live above ground biomass

C_{29} = taper coefficient (V8), see App. C

I_{47} = fractional crown cover

I_{37} = succession factor

I_{36} = daily structural biomass competition factor, g/m²

I_{135} = virtual stand volume, ft³, for setting radial growth rate of boles

$$85. \quad I_{135i} = 0.142 * I_{27i} * C_{29i} * (1 - I_{47i}/2)/(I_{37i} * I_{36i})$$

I_{135} = virtual volume, ft³, required for setting radial growth rate of stand boles for ith plant

I_{27} = g/m² live above ground biomass

C_{29} = taper coefficient (V8), see App. C

I_{47} = fractional crown cover

I_{37} = succession factor

I_{36} = daily structural biomass competition factor, g/m²

$$86. \quad I_{137k} = I_{144k}/3 \quad k = 1$$

$$= I_{144k} * 77.3/I_{1391} \quad k > 1$$

I_{137} = volume, ft³, of kth diameter class for ith plant
 I_{139} = wood of stand, ft³
 I_{144} = volume of average tree, ft³

$$87. \quad I_{1381} = I_{140k} * (I_{1391} * I_{1411} + C_{291}/2)^2 * (I_{1391})^2$$

I_{138} = total advantage factor for kth diameter class of ith plant
 I_{140} = number of trees/acre
 I_{139} = class diameter index, inches
 I_{141} = bole to crown conversion factor
 C_{29} = taper coefficient (V8), see App. C

$$88. \quad I_{140k} = X_{20k}/I_{144k}$$

I_{140} = number of trees/acre for kth diameter class of given plant
 X_{20} = volume, ft³
 I_{144} = volume of average tree, ft³

$$89. \quad I_{142k} = I_{1341} * I_{138k} / \sum_{k=2}^n I_{138k} \quad 2 \leq n \leq 60$$

I_{142} = growth allocation factor, ft³, for kth diameter class of ith plant
 I_{134} = growth increment, ft³/yr
 I_{138} = total advantage factor for biomass allocation

$$90. \quad I_{1431} = I_{1351} - \sum_{i=1}^n X_{20k}$$

I_{143} = volume difference between stand generated volume and calculated volume of ith plant
 I_{135} = wood of stand, ft³
 X_{20} = volume, ft³ of kth diameter class

$$91. \quad I_{144k} = 0.5 * 0.035 * I_{1451}/C_{291}) * (2 * 24 * 2.54)^2 \quad i = 1$$

$$= (0.035) * (I_{1451}/C_{291}) * [(i * (I_{1321} - 1/2))^2 + (i * (I_{1321} + 1/2))^2]/2 \quad 2 \leq i \leq 60$$

I_{144} = volume of average tree, ft³ of kth diameter class of ith plant
 I_{145} = specific gravity of wood
 I_{132} = size of diameter class intervals
 C_{29} = taper coefficient (V8), see App. C

92.

$$I_{148i} = \sum_{k=1}^n X_{20k}$$

I_{148} = cumulative total activity, activity/gram, of total stand for ith plant type

X_{20} = volume, ft³ of kth diameter class

93. $I_{150k} = (X_{20k})_p / (X_{20k} / 0.142)$

I_{150} = specific activity, activity/gram, for kth diameter class of given plant

X_{20} = volume, ft³

p = TRU pool material

94. $I_{150k} = I_{150k} - I_{150k-1}$

I_{150} = specific activity, activity/gram, for kth diameter class of a given plant

95. $I_{151j} = I_{66j} * (X_{6j} * I_{74j} + (1 - I_{74j}) * X_{7j} * X_{8j} / I_{27j}) * I_{75j}$

I_{151} = sum of total nitrogen concentration $\times 100$ for jth plant type

I_{66} = nitrogen content, percentage, of consumed biomass

X_6 = needle or leaf biomass, kg/m²

X_7 = g/m² of dead standing biomass

I_{74} = fraction of diet composed of green biomass

I_{27} = g/m² live above ground biomass

I_{75} = utilization efficiency, fraction of standing green forage

96. $I_{152i} = 30 * I_{78i}$

I_{152} = water content, percentage, of consumed biomass for ith plant type

I_{78} = nitrogen content, percentage, of standing green biomass

97. $I_{153} = 0.456$

$$I_{821} \geq 1.8$$

$$= 0.023 * (I_{821} - 0.6) + 0.0186$$

$$0.6 \leq I_{821} < 1.8$$

$$= 0.031 * I_{821}$$

$$0 \leq I_{821} < 0.6$$

I_{133} = grams/kcal of microprotein in digestible fraction

I_{82} = nitrogen content of ingested forage, %

II. EQUATIONS INVOLVING DRIVING VARIABLES

1. $D_2 = [(I_7 - I_8/2) * [\sin(2\pi * (I_8 - I_9)/365) + 1] + I_8$

D_2 = daily temperature, °C

I_7 = maximum monthly temperature, °F, average on daily basis

I_8 = day number

I_9 = lag period to maximum temperature

$$2. \quad D_2 = D_2 + I_{10} * (I_{11} - I_{12}) + I_{13}$$

D_2 = daily temperature, °C

I_{10} = lapse rate, °F/ft rise from reference site

I_{11} = reference elevation, feet above sea level

I_{12} = elevation of site, feet above sea level

I_{13} = latitude relative to reference site

$$3. \quad D_2 = (D_2 - 32) * 5/9 + S_8 * I_{14}$$

D_2 = daily temperature, °C

S_8 = random number drawn from a normal distribution ($m = 0$, $\sigma = 1$)

I_{14} = maximum temperature variation, °F, on a monthly basis

$$4. \quad D_3 = [(I_{24} - I_{25})/2] * [\sin(2\pi * (I_5 - I_{26})/365) + 1] + I_{26}$$

D_3 = solar radiation, Ly/day, on day I_5

I_{24} = maximum solar radiation, Ly/day, received during the year

I_{25} = minimum solar radiation, Ly/day, received during the year

I_{26} = lag period to maximum insolation, days

I_5 = day number

III. EQUATIONS INVOLVING LOGIC AND BOUNDARY VARIABLES

$$1. \quad \begin{aligned} L_1 &= F(P,1) & D_2 &> 0 \\ &= F(P,2) & D_2 &= 0 \end{aligned}$$

L_1 = temperature greater than 0°C

$F(P,1)$ = transport of water from precipitation events to soil

$F(P,2)$ = transport of water from snow to soil

D_2 = daily temperature, °C

$$2. \quad L_{701} \leq 733 * (I_{132}/2) * (1 - 0.5 * I_{471}) = I_{1331}$$

L_{101} = virtual stand volume, ft³, greater than minimum volume for given biomass density required for Forman access for ith plant category

I_{132} = size of diameter class intervals

I_{47} = fractional crown cover for specific plant

I_{133} = minimum volume, ft³, for given biomass density which is required for Forman access

IV. EQUATIONS INVOLVING STOCHASTIC VARIABLES

$$1. \quad S_1 = S_1 / \sum_{j=1}^I S_j$$

S_1 = random number drawn from a normal distribution ($m = 0$, $\sigma = 1$)

I_4 = total rainfall events/month totaling more than 0.1" precipitation

S_j = stochastic variables, see App. C

V. EQUATIONS INVOLVING STATE VARIABLES

$$1. \quad X_1 = X_1 + 25.4 * I_{831} \quad I_5 = I_{82k}$$

$$= X_1 \quad I_5 = I_{82k}$$

X_1 = current value of soil moisture availability
 I_{83} = succession ranking according to dominance for ith plant
 I_{82} = harvesting schedules, day number
 I_5 = day number

$$2. \quad X_5 = 0.928 * I_{27} * \text{EXP}(-3.11 * I_{27}) + 0.072 * I_{27}$$

X_5 = needle or leaf biomass, kg/m²
 I_{27} = g/m² live above ground biomass

$$3. \quad X_5 = C_{15} * I_{28} \quad X_5 \geq C_{15} * I_{28}$$

$$= X_5 \text{ (previous calculation)} \quad X_5 < C_{15} * I_{28}$$

X_5 = needle or leaf biomass, kg/m²
 I_{28} = running average productivity, kg/m²/yr
 C_{15} = leaf biomass allocation, see App. C

$$4. \quad X_5 = X_5 \quad L_4 = 1$$

$$= X_5 \quad L_4 = 0, I_{31} + 1 < I_5 < I_{32} + 1$$

$$= 1.0 \quad L_4 = 0, I_{31} + 1 > I_5 > I_{32} + 1$$

X_5 = needle or leaf biomass, g/m²
 L_4 = determines whether leaf fall occurs at end of frost-free period (0) or if evergreen (1)
 I_{31} = beginning of frost-free period, day number
 I_{32} = end of frost-free period, day number
 I_5 = day number

$$5. \quad X_{161} = 200 * C_{331}$$

X_{16} = microprotein level, grams, in rumen for ith age group of a given animal type
 C_{33} = initial weight of animal unit by age kg, see App. C

$$6. \quad X_{201} = I_{1331} * \text{EXP}(-1/C_{271}) * (I_{1351} - I_{1331}) \quad X_{201} > I_{1371}$$

$$= 0 \quad X_{201} \leq I_{1371}$$

X_{20} = volume, ft³, of the first diameter class of ith plant
 I_{133} = minimum volume for given biomass density required for Forman access
 C_{27} = mean average life-span, yrs, see App. C
 I_{136} = virtual stand volume, ft³, required for setting radial growth rate of stand boles
 I_{137} = minimum volume, ft³, of first diameter class required for estimation of X_{201}

$$7. \quad X_{202} = I_{1881} - X_{201}$$

X_{20} = volume, ft³, of second diameter class of ith plant category

I_{188} = virtual stand volume, ft³, required for setting radial growth of stand boles

$$8. \quad X_{20k} = X_{20k} * I_{1881}/I_{1881}$$

X_{20} = volume, ft³, for kth diameter of ith plant category

I_{188} = virtual stand volume, ft³, required for setting radial growth of stand boles

I_{188} = wood of stand, ft³

$$9. \quad X_{20k} = X_{20k} * (I_{1481}/(X_5 + X_4))_i$$

X_{20} = volume, ft³, for kth diameter of ith plant category

I_{148} = total activity, activity/gram, of total stand, cumulative

X_4 = g/m² live above ground biomass

X_5 = needle or leaf biomass, kg/m²

$$10. \quad a) \quad (X_4 + X_5) = 0.0$$

$$b) \quad X_3 = 0.0$$

$$c) \quad (X_4 + X_5) = (X_4 + X_5) * (20/I_{27})$$

$$d) \quad X_3 = X_3 * (20/I_{27})$$

$$k = 2; I_5 = I_{84k}$$

$$I_5 = I_{82,k}; 2 \leq k \leq 8, I_{27} > 20.0$$

X_3 = g/m² live root biomass

X_4 = g/m² live above ground biomass

X_5 = needle or leaf biomass, kg/m²

I_5 = day number

I_{27} = g/m² live above ground biomass

I_{82} = harvesting schedules, day number

I_{84} = harvesting schedules, day number

APPENDIX C

VARIABLES AND THEIR MNEMONIC EQUIVALENTS

Intermediate Variables Listing (Ii)

Ii	Array Size	Code Symbol	Program Location			
			PLA	FMG	FCT	ANL
1	12	X	*			
2	1	SNM	*			
3	1	SOILF	*			
4	1	TRE	*			
5	1	AIII	*			
6	1	PRCV	*			
7	1	T4	*			
8	1	T3	*			
9	1	L2	*			
10	1	ALPSR	*			
11	1	RELV	*			
12	1	G1	*			
13	1	L3	*			
14	1	TMXV	*			
15	1	H	*			
16	1	F1	*			
17	1	W1	*			
18	1	E2	*			
19	1	SDPTH	*			
20	22	EA	*			
21	22	E5	*			
22	22	E7	*			
23		M1	*			
24		T2	*			
25	1	T1	*			
26	1	L1	*			
27	22	B1	*	*	*	*
28	22	TPGNW	*			
29	22	WUYAW	*			
30	1	Y2	*			
31	1	SFFP	*			
32	1	EFFP	*			
33	1	WUTP	*			
34	22	B5	*			
35	1	EWAT	*			
36	22	CFAC	*	*	*	
37	22	SFAC	*	*	*	
38	1	AP	*			
39	22	CUTA	*			*
40	1	H2	*			
41	1	H3	*			

Intermediate Variables Listing (Ii) (cont)

<u>Ii</u>	<u>Array Size</u>	<u>Code Symbol</u>	<u>Program Location</u>			
			<u>PLA</u>	<u>FMG</u>	<u>FCT</u>	<u>ANL</u>
42	1	RSUSP	*			
43	1024	AMAC	*			
44	1	AIRCA	*			
45	1200	AA		*	*	
46	1	A11	*			
47	22	CCVV	*	*	*	
48	365	P	*			
49	22	TLAI	*			
50	1	BP	*			
51	704	Z1	*			*
52	704	ZU	*			
53	704	ZF	*			
54	1	IICDE	*			
55	1	RPNTP	*			
56	22	STBR	*			
57	704	ZF	*			
58	1	ADD	*			
59	1	B111 + R111	*			
60	22	1 B7 1	*			
61	336	DIRA	*			
62		CUTA(I ₉₉)	*			
63		CUTA(I ₉₉)	*			
64		CUTA(I ₉₉)	*			
65		DIRA(I ₉₁)	*			
66	22	CNIT				*
67		SFAC(I ₉₇)				
68		SFAC(I ₉₇)	*			
69	1	STBMX	*			
70	88	PUTZD				*
71	3	QFRAC				*
72	3	QSUM				*
73	4	SPUT				*
74	22	G				*
75	22	A				*
76	22	P4				*
77	22	PNIT				*
78	22	SNIT				*
79	22	PP6				*
80	3	UP				*
81	1	O				*
82	1	N				*
83	1	GA				*
84	3	GTDR				*
85	8	SPAC				*
86	3	SACT				*
87	8	SPAR				*

Intermediate Variables Listing (Ii) (cont)

Ii	Array Size	Code Symbol	Program Location			
			PLA	FMG	FCT	ANL
88	3	SAIR				*
89	4	HRVST				*
90	22	ACRES	*	*	*	*
91	1	SPAS				*
92	1	SPAA				*
93	4	HRVSP				*
94	1	SPAP				*
95	1	SAAP				*
96	1	SPAS				*
97	1	SPAA				*
98	1	A1TT	*			*
99	22	Z1	*	*	*	*
100	1	HERD				*
101	8	Z*HERD				*
102	1	W3				*
103	32	M				*
104	32	R				*
105	1	DDI				*
106	1	H				*
107	1	H1				*
108	1	F2				*
109	1	E				*
110	32	S				*
111	1	X1				*
112	1	BB				*
113	1	E1				*
114	1	E2				*
115	1	E4				*
116	1	GSUPF				*
117	1	E5				*
118	1	C2				*
119	1	C4				*
120	1	M5				*
121	1	M6				*
122	4	AA2				*
123	22	TSUMB				*
124	1	C3				*
125	4	N5				*
126	4	FSUPF				*
127	4	TOTSF				*
128	1	C5				*
129	32	Y				*
130	32	X				*
131	4	P5				*
132	22	XJ1				
133	1	T2		*		
134	1	G4		*		

Intermediate Variables Listing (Ii) (cont)

<u>Ii</u>	<u>Array Size</u>	<u>Code Symbol</u>	<u>Program Location</u>			
			<u>PLA</u>	<u>FMG</u>	<u>FCT</u>	<u>ANL</u>
135	1	V5		*		
136	1	V4		*		
137	1320	VTMBR	*	*	*	*
138	60	X		*		
139	1	AN		*		
140	1320	DTBR	*	*	*	
141	22	C6		*		
142	1	G3		*		
143	1	V4M6		*		
144	60	Z		*		
145	22	C9		*		
146	22	ACTS		*		
147	1	VDTBM		*		
148	1	TOTAC		*		
149	1	TOTSA		*		
150	1320	SATB		*	*	*
151	3	TNIT				*
152	22	WATER				*
153	1	M2				*

Driving Variables (Di)

<u>DI</u>	<u>Array Size</u>	<u>Code Symbol</u>	<u>Program Location</u>			
			<u>PLA</u>	<u>FMG</u>	<u>FCT</u>	<u>ANL</u>
1	1	R	*			
2	1	T	*			
3	1	AKK	*			

Logic and Boundary Variables (Li)

<u>Li</u>	<u>Array Size</u>	<u>Code Symbol</u>	<u>Program Location</u>			
			<u>PLA</u>	<u>FMG</u>	<u>FCT</u>	<u>ANL</u>
1	1	T ≥ 0	*			
2	1	BAP (0,1)	*			
3	1	BCP (0,2)	*			
4	1	ISTP (0,1)	*			
5	22	SCTP (0,2)	*			
6	1	IYR ≥ 0	*			
7	1	CHRSY ≥ 0	*			
8	128	YRGRZ:AI1				*
9	128	ONRNG(AIII)				*
10	1	V5 > T1		*		

Stochastic Variables (Si)

Si	Array Size	Code Symbol	Program Location			
			PLA	FMG	FCT	ANL
1	1	G5	*			
2	NRE*	NN	*			
3	1	G4	*			

*See Variable Library (App. D)

User Option Variables (Oi)

Oi	Array Size	Code Symbol	Program Location			
			PLA	FMG	FCT	ANL
1	22	$RSS \geq 0$	*			
2	1	RSCDE(0,1)	*			
3a	1	$XPLNT \geq 0$				
3a	22	$RGC \leq 3$ (daily)	*			
3b	22	$RGC \leq 2$ (yearly)	*			
4	1	$TBRM \geq 0$		*		
5	1	RHERB (0,2)	*			
6	22	RIRRC (0,2)	*			

State Variable (Xi)

Xi	Array Size	Code Symbol	Program Location			
			PLA	FMG	FCT	ANL
1	1	S1	*			
2	1	F7	*			
3	22	R1	*	*	*	*
4	22	B1	*	*	*	*
5	22	WND	*	*	*	*
6	22	RD1	*	*	*	*
7	22	D1	*		*	*
8	22	RH1	*			
9	22	H1	*			
10	704	Z1	*	*	*	*
11	22	A2	*	*	*	*
12	22	AAA	*			
13	32	R				*
14	32	W				*
15	8	W				*
16	32	P				*
17	32	U				*
18	32	Q				*
19	1320	DTBR		*	*	*
20	1320	VTMBR	*	*	*	*

Constants

Ci

1.	Snow melt coefficient	1.128 mm/°C
2.	Evapotranspiration intercept	0.6 mm
3.	Evapotranspiration proportionality	0.18 mm/day
4.	Soil depth adjustment	0.632
5.	Soil depth exponential adjustment	0.004
6.	Optimum growth temperature	°C
	25 (1,*2,3,5,7,8)	
	18 (12,13,15,18,19)	
	21 (4,6,9,10,11)	
	15 (16,20,21)	
	14 (14)	
	12 (17)	
7.	Effect of temperature, above optimum	°C ²
	81 (1,2,3,5,7,8)	
	169 (4,6,9,10,11)	
	256 (12,13,15,18,19)	
	400 (14)	
	484 (17)	
	361 (16,20,21)	
8.	Effect of temperature, below optimum	°C ²
	225 (1,2,3,7,8)	
	169 (12,13,18,19)	
	121 (4,6,10,11)	
	625 (5)	
	441 (9)	
	196 (14)	
	324 (15)	
	100 (16,21)	
	144 (17)	
	225 (20)	
9.	Effect of soil moisture on photosynthesis	
	5.0 (1,2,3,4,5,6,7,8,9)	
	3.0 (10,12,13,14,15,16,17,18,19,20,21)	
	4.0 (11)	
10.	Effect of solar radiation on photosynthesis	0.001/Ly/day
11.	Respiratory maintenance component (ARP)	
	0.0 (1,2,3,7,8,11,12,13,18,19)	
	1.5 (4,10,21)	
	2.0 (6,14,16)	
	3.0 (15,17,20)	
	5.0 (5,9)	
12.	Respiratory effect 1	
	0.01 (1,2,3,4,5,6,7,8,9,10,11,15)	
	0.03 (12,13,14,16,17,18,19,20,21)	
13.	Respiratory effect 2	
	0.161 (1,2,3,4,5,6,7,8,9,10,11)	
	0.153 (15)	
	0.120 (12,13,14,16,17,18,19,20,21)	

*Plant numbers, see variable library.

Constants (cont)

Ci		
14.	Respiratory effect 3 0.13 (1,2,3,4,5,6,7,8,9,10,11) 0.20 (15) 0.18 (12,13,14,16,17,18,19,20,21)	
15.	Leaf biomass allocation 1.0 (5,9,14,15,17,20) 0.5 (4,6,10,16,21)	
16.	Minimum water utilization efficiency (WUTP) 350 (1,2,3,4,7,8,11,12,13,18,19) 725 (5,9,14,15,17,20) 900 (6,10,16,21)	ml/g
17.	Hatch-slack coefficient (PSE) 0.5 (1) 1.0 (all other plants)	
18.	Fraction of photosynthate transferred to roots (RTRANS) 0.7 (3,8,13,18) 0.25 (1,2,6,9,12,16,20) 0.15 (4,5,10,14,15,17,21) 0.5 (7,11,19)	
19.	Fraction of photosynthate remaining above ground (STRANS) 0.3 (3,8,13,18) 0.75 (1,2,6,9,12,16,20) 0.85 (4,5,10,14,15,17,21) 0.5 (7,11,19)	
20.	Mortality factor 1 0.05 (1,2,11,12) 0.10 (3,7,8,13,17,18,19)	
21.	Mortality temperature effect 25 (1,2,3,7,8) 21 (11,12) 18 (13,18,19)	°C
22.	Mortality factor 2 0.1 (1,2,3,7,8,11,12,13,18,19)	
23.	Mortality factor 3 1.1 (1,2,3,7,8,11,12,13,18,19)	
24.	Mortality factor 4 0.1 (1,2,3,7,8) 0.14 (11,12) 0.2 (13,18,19)	
25.	Mortality factor 5 0.1 (1,2,12)	
26.	Mortality temperature factor, lower 10 (1,2,3,7,8) 7 (11,12) 5 (13,18,19)	°C
27.	Mean average life-span (HF) 1 (1,2,7,12,19) 30 (3,8,11,13,18) 70 (6,9,16,20) 150 (4) 175 (10,21) 300 (5,14,15,17)	years

Constants (cont)

Ci		
28.	Initial activity in atmosphere (CHRAc)	ACT/m ²
29.	Taper coefficient (V8)	
	1.0 (1,2,3,4,6,7,8,9,10,11,12,12,14,16,18,19,20,21)	
	0.8 (17)	
	1.36 (15)	
	2.5 (5)	
30.	Effective succession life-span (RSCF)	
	C _{st} (1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18,20,21)	
	9.0 (19,7)	
31.	Nitrogen content of dry forage (N3)	0.6%
32.	Fraction of population by age (Z)	
	Animals 1,2 (0.4,0.06,0.12,0.18,0.12,0.06,0.036,0.024)	
	Animals 3,4 (0.25,0.23,0.16,0.12,0.12,0.05,0.05,0.02)	
33.	Initial weight of beef cattle by age (W)	kg
	1-8 yrs (23,290,410,494,550,550,550,550)	
34.	Area of regional grid (M7)	3.73 × 10 ⁶ m ²
35.	Diameter class intervals	(0.2;2) inches

APPENDIX D
VARIABLE LIBRARY

Symbol	Location*	Definition
A	1	Mid range solar radiation value Ly/day
A(22)	4	Utilization efficiency, fraction of standing forage
AA	2,3	Call statement (see Main Program, AAA(1))
AAA(22)	1	Activity/m ² from fire increment to total air activity
AAKK	1	Counter for plant types included in succession module
AATB(22,60)	2,3	Average age of trees(l) with diameter(k)
AA2(4)	4	Input variable, fraction of region grazed by specific animal unit
ABC	1	Difference between real value of Q(l) and integer value of Q(l)
AC	1	Root respiration factor for some plant types
ACRES(22)	1,2,3,4	$v = \text{acres/plant}(i)$, ($i = 1,22$) $0 \leq v \leq \text{grid size}$. For $v = 0$, grid size assumed ($v = \text{size, acres}$)
ACTAV	2	Geometric mean of stand, specific activity, activity/gram
ACTS	2	Logarithmic sum of class diameter specific activity
ACUT(22,2)	3	Input variable, lower & upper diameters selected for cutting in "A" class cut selection
ADD	1	Biomass transpiration coefficient, day ⁻¹
AGAVE	2	Geometric mean of stand age, years
AGSUM	2	Logarithmic sum of class diameter ages, years
AGTB(22,60)	1,2,3	Minimum age (yrs) of plant(l) with diameter(k)
AI1	1,2,3,4	I1, year number

1 = Main Program, 2 = Forman, 3 = Forcut, 4 = Rmnan.

Symbol	Location*	Definition
AICHE	1	Input variable, indicates if niche competition will occur, for output purposes only
AIII	1,4	III, day number
AI1P	1	Product of year number $\times$ 365
AIRCA	1	Activity/m ³ in air, for chronic activity function
AKK	1	Solar radiation Ly/day on day K3
ALPSR	1	Input variable, lapse rate, °F/ft rise from reference site
AL9	2	Class diameter index, inches
AMAC(16,64)	1	Input variable, specifies amount of atmospheric activity/m ³ on a given day (64 day event possible) for a given year (16 separate or continuous years possible)
AN	2	Class diameter index, inches
ANMAL(4,32)	4	Input variable, number of animals grazing during each interval of a given year
ANOT	1,2	Alphanumeric literal used for output purposes only
AP	1	Factor to determine mortality of certain plant types
AQ	1	I1
ARIG	1	Input value, determines if irrigation schedule will be used. For output purposes only
ARP	1	Respiration increment in leaf biomass multiples
AWATA(22,16)	1	Input variable, irrigation water applied, acres/inches
A1(22)	1,2,3,4	Activity/m ³ air concentration from all sources
A1TT	1,4	Weighted average activity/m ³ over several plant species
A1Z	1	Air activity/m ³ due to soil resuspension
A2(22)	1,2,3,4	Activity/m ³ on leaf surface of specific plant
A22	1	Activity/gram for leaf biomass due to deposition

Symbol	Location*	Definition
A23	1	Concentration ratio between deposition activity/ soil activity
A55	4	Total number of animals on and off range
B	1	Mid range monthly temperature, °F, for site
B	2	Adjusted biomass of stand g/m ² to account for succession and competition
B	4	Total green and dry biomass, g/m ² available for consumption
BAAV	2	Logarithmic sum of bole diameters for stand
BAP	1	(0 or 1) determines whether photosynthesis is occurring
BAR(60)	2	Bole diameter, inches
BARSQ(60)	2	BAR ² , sum of squares of log bole diameters
BATR	2	Geometric mean tree height, ft
BB	4	Fatty acid energy, kcal
BBP(22)	2	Previous year (day) above ground biomass g/m ²
BCP	1	(0 or 1) determines whether respiration is occurring
BCUT(22,2)	3	Input variable, lower and upper diameters selected for cutting in "B" class cut selection
BLANK	1,2	Alphanumeric literal used for output purposes only
BMN	2	Geometric mean of bole diameter, inches
BP	1	Edible portion of plants, g/m ²
BSD	2	Geometric standard deviation for basal area
BSQ	2	Sum of squares of logarithmic basal area
B1(22)	1,2,3,4	g/m ² of live above ground biomass. $1 \leq V$
B111	1	kg/m ² , above ground biomass for specific plant
B2	2	Diameter of 0-2 class, inches
B5(22)	1,2,3,4	Net daily biomass production, g/m ² /day
B7(22)	1	Net daily biomass production shunted to roots, g/m ² /day

Symbol	Location*	Definition
C	1	Amount of water required for photosynthesis, ml/m ² /g CH ₂ O
CCUT(22,2)	3	Input variable, lower and upper diameters selected for cutting in "C" class cut selection
CCVV(22)	1,2,3,4	Fractional crown cover for specific plant(k)
CFAC(22)	1,2,3,4	Daily structural biomass competition factor, g/m ²
CHRA	1	Input variable, initial activity in atmosphere/m ² for chronic activity function (0.0 or value greater than 0.0 required)
CHRED	1	Input variable, day of final acute contamination (day number is 1.0-365.0 or 0.0 required)
CHREY	1	Input variable, year of chronic contamination
CHRS	1	Input variable, day of initial acute contaminating event (day number is 1.0-365.0 or 0.0 required)
CHRSY	1	Input variable, year of initial contaminating chronic event (0.0 or value greater than 0.0 required)
CNIT(22)	4	Nitrogen content, percentage, of consumed biomass
COV(60)	2	Product of No. of trees × diameter class crown cover for lth diameter class, m ²
COVAV	2	Sum of crown cover for stand
COVSQ(60)	2	COV(l) ² sum squares
CUTA(22,8)	1,2,3,4	Input variable, harvesting schedules, day of year
CVAG	1	Total weighted cover of grid due to all plants
CVMN	2	Mean of crown cover
CVMN(22)	1	Crown cover factor used in adjusting total acreage to grid acreage
CVSD	2	Geometric standard deviation crown cover for stand
CVSQ	2	Sum of squares for log crown cover
CVTR	2	Basal area cover, m ²
CVTT	1	Weighted average crown cover of 2 or more plant types

Symbol	Location*	Definition
CSFAC(22)	1	CFAC(22)
CYR	1	Input variable, specifies the total number of years of an acute event (0.0 or value greater than 0.0 required)
C1	4	Rumen capacity, kg
C2	4	Total weight of forage consumed, grams
C3	4	Total activity ingested from forage
C4	4	m ² grazed by all animal units in a given age group
C5	4	Soil ingestion, grams/day
C6(22)	2	Crown diameter to bole diameter intercept value
C6	4	Activity entering blood/day from soil ingestion
C7	4	Fraction air deposition entering blood via GI
C7	1,2,3	Sum of total volume of all trees for plant(k)
C9	4	Activity entering blood from forage (total)
C9(22)	2	Input variable, specific gravity of wood
D	1	Ratio of difference between day no. and Lag period to day of maximum insolation/365
D(22)	4	Fraction of diet composed of dry biomass for kth plant
DAIC(16)	1	Input variable, determines initial day of acute event for all years involved (1.0-365.0)
DATCT(22,32)	1,2,3,4	Input variable, stores the years (days) of specific management generations: cutting, forest fire, etc.
DD1	4	Digestible fraction of ingested forage
DD2	4	Total potential digestibility kg/day
DF	2	Degrees of freedom for cumulative summations
DGTMB	2	$\Delta VTMBR(JK,1), \text{year}^{-1}$
DIFF	1	Factor which adjusts deepest soil horizon root fraction

Symbol	Location*	Definition
DIRA(22,16)	1	Input variable, irrigation schedule, day of year, when water is applied
DLY	1,2	Alphanumeric literal used for output purposes only
DRMM	1	Precipitation, mm
DTBR(22,60)	1,2,3	Number of trees/acre for plant(k) with diameter(l)
DURC	1	Input variable, duration of an acute event, days (0.0 or value greater than 0.0 required)
D1(22)	1,3,4	g/m ² of dead standing biomass for specific plant
D3	1	Dead increment/day added to mortality losses g/m ² /day
D3	4	Change in rumen dry matter kg/day
D4	4	Weight of dry forage consumed
E	1	Ratio of difference between day no. and lag period to day of maximum temperature/365
E	4	Rumen exit rate, fraction/day
EA(22)	1	Adjusted evapotranspiration rate, mm/250 mm
EFFP	1	End of frost-free period, day number
EWAT	1	g/m ² , biomass net production on a given day
E1	4	Energy from passed food, kcal
E2	1	Potential evapotranspiration rate, mm, from top 250 mm soil
E2	4	Energy from microprotein, kcal
E4	1	EA(l) for lth plant series
E4	4	Net available energy, kcal
E5(22)	1	Effect of temperature (°C) on photosynthesis for plant(l)
E5	4	Fraction of available energy for growth, kcal
E6	4	Rate at which food passes through GI, fraction
E7(22)	1	Effect of soil moisture on photosynthesis for plant(l)

Symbol	Location*	Definition
F	1	Ratio of day number/365
FDIET	4	Fraction of diet, specific plant, for animal unit
FFP	1	Input variable, frost-free period of site, days
FRCT	1	Input variable, indicates call for Forcut Sub-routine, for output purposes only
FRMN	1	Input variable, indicates call of Forman Sub-routine, for output purposes only
FSUPF(4)	4	Input variable, fraction of supplementary feed from study area
F1	4	Normal fermentation rate, fraction of intake/g microprotein/day
F1	1	Input variable, field capacity of soil, % H ₂ O
F2	4	Fermentation digestion rate, fraction/kg
F7	1	mm, precipitation as snow
G(22)	4	Fraction of diet composed of green biomass for kth plant
GA(60)	2,3	Difference in age between youngest and oldest tree in lth class diameter interval
GA	4	Cumulative green biomass uptake for kth food preference category
GGTM	2	Volume for given class diameter (GTMBR)
GGTMB	2	GTMBR (JK,1)
GSUPF	4	Supplementary feed required, grams
GTDR(3)	4	Available green standing biomass for ith preference category
GTMBR(22,60)	1,2,3,4	Current year virtual volume, ft ³ , for plant(l) and diameter(k)
G1	1	Input variable, elevation of site, feed above sea level
G1	4	Weight green forage consumed, grams
G3	2	Growth allocation factor, ft ³

Symbol	Location*	Definition
G30	2	Growth allocation factor, ft ³
G4	1	Random number drawn from a normal distribution $m = 0, \sigma = 1$)
G4	2	Growth increment, ft ³ /year for specific plant(l) in a given year
G5	1	Random number drawn from a normal distribution ($m = 0, \sigma = 1$)
H	1	Input variable, holding capacity of soil, % H ₂ O
H	4	Energy in digestible fraction of intake, kcal
HD	4	Total number of animal units on range, maximum
HDD	4	Total number of animal units off range (on supplementary feed)
HERD	4	Number of animal units on range for given grazing interval
HF	1	Average life-span of plant species
HGT(60)	2	Height for trees in given diameter class, ft
HGTSQ(60)	2	HGT(l) sum of squares
HRVSP(4)	4	Previous year biomass, grams, available to kth animal category as supplementary feed
HRVST(4)	4	Biomass, grams, available to kth animal category from all plants utilized as supplementary feed during current year
HTAV	2	Mean height, feet, for stand
HTSD	2	Standard deviation for stand height
HTSQ	2	Sum of squares for log stand height
HUMUS(4)	4	Activity/m ² added to humus compartment from kth animal category
H2	4	Microprotein in rumen, grams
H1(22)	1,4	g/m ² above ground litter-humus
H2	1	Dead biomass temperature decay factor
H3	1	Dead biomass soil moisture decay factor

Symbol	Location*	Definition
I	1	Index for months of year
IA1	3	ACUT(k,1), portion of stand removed, lower diameter, inches
IA2	3	ACUT(k,2), portion of stand removed, upper diameter, inches
IBRM	2,3	TBRM(l), number of tree management events
IB1	3	BCUT(k,1), portion of stand removed, lower diameter, inches
IB2	3	BCUT(k,1), portion of stand removed, upper diameter, inches
ICA(22)	1,2,3,4	Day counter for harvesting schedule
ICAAA	1	ICA(l)
ICDY	1	Year counter
ICYR	1	Year counter
IC1	3	CCUT(k,1), portion of stand removed, lower diameter, inches
IC2	3	CCUT(k,1), portion of stand removed, upper diameter, inches
IDUR	1	DURC
IICDE	1	Defines number of soil horizons in 250 mm intervals. $1 \leq V \leq 32$. (V = value)
III	1,2,3,4	Day number
IJ	1	Integer value of number of years simulation
IN	4	Animal category $1 \leq V \leq 4$. (V = value)
INWRT	2	TNWRT(l)
INPUTZ	4	PUTZD(j,k)
IRG(22)	1	Day counter for irrigation schedule
IRGGG	1	IRG(j)
ISTP	1	Determines whether leaf fall occurs at end of frost-free period(0) or if evergreen(1)

Symbol	Location*	Definition
ITC	3	TCUT(j,k)
IXX	4	ICA(l), see Main Program
IYR	1	CYR
I1	1,2,3,4	Year counter
I12	4	Switching value for initialization(1) or shunt (>1)
I7	1	Integer value of RANDN (a random number seed)
K3	1	Real value of day number ($1 \leq K3 \leq 355$)
L1	1	Input variable, lag period to maximum insolation, days
L1	4	Undigested food kg/day
L2	1	Input variable, lag period to maximum temperature
L2	4	Passed undigested food kg/day
L3	1	Input variable, latitude relative to reference site (0.0,1.0,-1.0)
L4	4	Fraction of activity from pulmonary deposition absorbed into blood via stomach/day
L5	4	Fraction of activity entering blood from pulmonary deposition/day
M	1	Day counter
M	2	MIND(l)
M(8,4)	4	Metabolic biomass (kg) for kth population category, lth animal category
MIND(22)	2	Year (day) counter for lth plant cycle through FORMAN
MM	1	Day counter
M1	1	Maximum photosynthetic efficiency (C_p —plants) (grams CH_4O/m^2) per (grams green biomass/ m^2)
M1	4	Microprotein passage rate g/g/day
M2	4	Grams/kcal of microprotein in digestible fraction

Symbol	Location*	Definition
M4	4	Microprotein/metabolic biomass ration g/kg
M5	4	m ² grazed by an age group of a given animal population
M6	4	Fraction of area grazed by an age group of a given animal population
M7	4	Area of region being grazed, m ² , by animal category (grid area)
N	4	Nitrogen content of ingested forage, %
NDAY(12)	1	Number of days in each month
NN	1	Integer value of Q(1) or integer value of Q(1) + 1
NRE	1	TRE
N2	4	Nitrogen content of daily photosynthate, %
N3	4	Nitrogen content of dry forage, %
N4	4	Nitrogen content of standing green forage
N5(4)	4	Input variable, number of animal units/category
O	4	Ingestion rate, kg/day
ONRNG(4,32)	4	Input variable, days on range for year intervals (100-290), (150-300), etc.
P	1	Daily precipitation events
P(8,4)	4	Microprotein level, grams, in rumen for kth age, lth animal
PI	1	Constant, 3.1416
PLNTS	1	Number of plant types in simulation
PNIT(22)	4	Nitrogen content, percentage, of photosynthate for lth plant category
PP6(22)	4	Initial leaf biomass for 22 plant categories
PRCV	1	Input variable, coefficient of variation for precipitation/event of reference site
PSE	1	PSEP

Symbol	Location*	Definition
PSEP	1	Distinguishes C ₄ —plant(1) or C ₃ —plant (0.5), photosynthetic efficiency
PUTZD(4,22)	1,2,3,4	Input variable, plants utilized by animal(1)
P1	1	Annual cumulative precipitation, mm
P2	4	Needle or leaf biomass g/m ² (green)
P3	4	Needle or leaf biomass g/m ² (dry standing)
P4(22)	4	Growth rate fraction/day for kth plant category
P5(4)	4	Input variable, fraction of muscle tissue and organs consumed in study area in that region
Q(24)	1	Product of random number (0-1) and number of days in given month
Q(8,4)	4	Accumulated activity entering pulmonary region for kth plant, lth animal
QDO	4	g/m ² of dry forage consumed by animal units of given age group/day
QFRAC(3)	4	Animal preference fraction for kth food preference category
QGO	4	g/m ² of green forage consumed by animal units of given age group/day
QSUM	4	Available forage g/m ² from all forage sources of ith preference category
Q1	1	Factor used in calculating effect of soil moisture on photosynthesis
Q8	1	Random number counter
Q10	4	Available forage for consumption on a daily basis g/m ² for specific plants utilized
R	1	Input variable, annual precipitations, inches
R(8,4)	4	Rumen capacity, kg, for a given age(yr) category of a specific animal category
RACUT(22)	3	Input variable, fraction of ACUT cut left standing
RANDN	1	Input variable, random number seed for a given run

Symbol	Location*	Definition
RANK(22)	1	Succession ranking according to dominance ($1 \leq V \leq 22$) for plant. (V = value)
RAP	1	Constant in plant respiration equation (gate)
RBCUT(22)	3	Input variable, fraction of BCUT cut left standing
RCCUT(22)	3	Input variable, fraction of RCUT cut left standing
RCODE(22)	1	Input variable, determines soil depth for specific plant type, mm
RD1(22)	1,2,3,4	g/m ³ dead root biomass
RD3	1	Daily mortality increment from roots g/m ³ /day
REEL	1	Number of soil horizons at 250 mm increments $\times 10$
RELV	1	Input variable, elevation, feet above sea level
RFC	1	Reciprocal of soil evapotranspiration factor at given soil depth
RFP	1	Constant in plant respiration equation (gate)
RGAIN	1	Activity/m ³ absorbed into roots in a specific soil horizon
RGC(22)	1,2,3,4	Input variable, selector for specific plants to be simulated
RHERB	1	Input variable, determines whether Rmnan Sub-routine is called g/m ³ root litter-humus
RH1(22)	1	g/m ³ root litter-humus
RINGT(22)	1,2,3,4	Diameter increment/tree of given diameter
RIRRC(22)	1	Input variable, determines whether irrigation schedule for plant type will be part of input
RNDD	1	Integer value of number of soil horizons at 250 mm $\times 10$
RPNTP	1	Root penetration, mm, as a function of total days elapsed
RR(4)	4	Input variable, indicates which of four animal types are simulated. Value = mature weight ratio of animal unit to mature weight of beef cow

Symbol	Location*	Definition
RSBIO(22)	1	g/m ² /day maintenance losses exclusive of leaf biomass
RSCDE	1	Input variable, determines whether succession module is used(1) or ignored(0)
RSCF(22)	1,2,3,4	Effective life-span for succession, years
RSS(22)	1	Input variable, determines which plant groups are to be considered for competition for available land area
RSUSP	1	Resuspension factor, day ⁻¹
RTRANS	1	Fraction of photosynthate translocated to roots
RVJ	3	"Reverse-j" cut equation, fraction for given diameter class
RXPP	1	Constant in plant respiration equation
R1(22)	1,2,3,4	g/m ³ live root biomass
R111	1	g/m ³ live root biomass
S(8,4)	4	Rumen fill, kg, for kth population age group of lth animal category
SAAP(4)	4	SPAA(4) from previous year
SACT(3)	4	Specific activity of ith preference category, activity/g
SAFP	1	Constant used in determining effect of soil moisture on photosynthesis
SAIR(3)	4	Specific activity, activity/g, for kth food preference category (surface contamination)
SAO	4	Specific activity, activity/g, derived from surface contamination
SATB(22,60)	1,2,3	Specific activity, activity/g, for plant(k) of diameter(l)
SCTP(22)	1,2,3,4	Distinguishes woody plants(0) from herb types(1)
SDPTH	1	Input variable, soil depth, mm (equals 0.0 if input via other card input, see RCODE) for site
SFAC(22)	1,2,3,4	Succession factor calculated on yearly basis

Symbol	Location*	Definition
SFCT	1	Sum of succession factor SFAC(22) for specific plants (intermediate sum 1)
SFFA	1	Sum of succession factor SFAC(22) for specific plants (intermediate sum 2)
SFFB	1	Sum of succession factor SFAC(22) for specific plants (intermediate sum 3)
SFFC	1	Sum of succession factor SFAC(22) for specific plants (final summation)
SFFP	1	Beginning of frost-free period, day number
SNIT(22)	4	Nitrogen content, percentage, of standing green biomass
SNM	1	Snow melt, as mm water
SOILF(22)	1	Soil evapotranspiration adjustment for soil depth
SOILP	1	Reciprocal of SOILF
SP	1	(0,1) controls uptake of activity below a given depth of soil
SPAA(4)	4	Total surface activity available to kth animal category for irrigated forage
SPAC(4)	4	Specific activity, activity/g, for given category consumed daily by kth animal category
SPAP(4)	4	SPAS(4) from previous year
SPAR(4)	4	Specific activity, activity/g, on surface for given food category consumed by kth animal category
SPAS(4)	4	Total activity available to kth animal category from irrigated forage
SPUT(4)	4	Total sum of plants utilized for kth animal category
STBMX	1	Maximum value of STBR(k)
STBR(22)	1	Structural biomass succession factor, g/m ² /yr running yearly average
STRANS	1	Fraction of photosynthate translocated to above ground biomass
SYAV	1	Cumulative sum of yearly interations, years

Symbol	Location*	Definition
S1	1	Current value of soil moisture availability
S10	4	Specific activity of consumed forage for internal absorption
T	1	Temperature °C on day K3
TAV	1	Average annual temperature, °F
TBRM(22)	1,2,3,4	Input variable, indicates how many managed cuttings or events will be simulated
TCR	2	Determines whether plant(l) is cycling on yearly(1) or daily basis (365) in Forman
TCUT(22,32)	3	Input variable, specifies type of cut or fire event or event parameter
TLAI(22)	1	Leaf area index m ² /m ² for specific plant category
TMXV	1	Input variable, maximum temperature variation, °F, on a monthly basis
TNIT(3)	4	Sum of total nitrogen concentration × 100 for ith preference group
TNWRT(22)	2	Input variable, indicates how many print-outs of tree structure are required. Maximum is 20
TOTAC	2	Total activity, activity/g, of total stand, cumulative
TOTSA	2	Above ground biomass for stand activity/m
TOTSF(4)	4	Total supplementary feed required by kth animal category on a given day
TPGNW(22)	1,2,3,4	Running average productivity kg/m ² /year
TRE	1	Total rainfall events/month totaling more than 0.1"
TREES	2	Total number of trees in stand
TSUMB	4	g/m ² of green and dry standing biomass
TY	1	Year counter
T1	1	Input variable, minimum solar radiation, Ly/day received during the year

Symbol	Location*	Definition
T1	2	Minimum volume for given biomass density required for Forman access
T111	1	Total respiration leaf and maintenance, g/m ² /day
T2	1	Input variable, maximum solar radiation, Ly/day received during the year
T3	1	Input variable, minimum monthly temperature, °F, average for site on a daily basis
T4	1	Input variable, maximum monthly temperature, °F average for site on a daily basis
T5	1	mℓ/m ² water evapotranspired/day
T5P(22)	1	mℓ/m ² water evapotranspired for a specific plant/day
T6	1	Potential amount of water required for photosynthesis mℓ/m ² /day
T8	1	Cumulative day counter
U(8,4)	4	Digestible dry matter, kg/day, intake rate for kth population group of lth animal category
UP	4	Uptake kg/day for ith preference categories
UPTKE	1	Input variable, uptake coefficient, fraction/day/mℓ transpiration/m ²
V(8,4)	4	Activity entering organism from all sources for kth animal categories
V(1,I)	4	Activity in new born animal units
VA(60)	2	Activity/m ² of lth class diameter for specific plants
VDTBM	2	ΔVTMBR(JK,1) for succeeding years
VCUT(60)	3	Residual volume of timber, ft ³ , after harvesting operation or fire
VOLTR	2	Volume of tree, "ft ³ ," of given diameter
VTMBR(22,60)	1,2,3,4	Volume, cubic feet, of plant(l) for diameter(k)
VTOT	3	Total volume of timber harvested for a specific type of cut

Symbol	Location*	Definition
VVTM	2	Current biomass volume, cubic feet
V2	2	Volume of 0-2 inch diameter class plant, ft ³
V3	2	Volume of 2-4 inch diameter class plant, ft ³
V4	2	Wood of stand, ft ³
V4M6	2	Volume difference stand generated volume and calculated volume
V5	2	Virtual stand volume, ft ³ , required for setting radial growth rate of stand boles
V6	2	Sum of volumes, ft ³ , for all class diameters
V8(22)	1,2,3,4	Taper coefficient relating stem diameter to above ground biomass and specific gravity of wood (final value). Regression coefficient – 1 bole diameter to biomass density (initial value)
W(8,4)	4	Biomass, kg, for 4 animal classes, 8 age groups
W(9,4)	4	Total activity/animal unit 3-8 year olds for 4 animal classes
W(10,4)	4	Average activity/animal unit for total herd
W(11,4)	4	Concentration in milk, activity, liter
W(12,4)	4	Average weight/animal unit for total herd
W(13,4)	4	Activity/kg in muscle tissue of herd (weighted ave)
W(14,4)	4	Activity/kg in liver (weighted ave)
W(15,4)	4	kg of muscle available to human population from herd
W(16,4)	4	Activity/kg in bone
WA(22)	1	Amount of water, mm, in top 250 mm adjusted for soil depth ^a $W1 \leq V \leq H$. (V = value)
WATER(22)	4	Water content, percentage, of consumed biomass
WND(22)	1,2,3,4	Leaf biomasses, g/m ² , for a specific plant
WN1	1	Needle or leaf biomass kg/m ²
WRSTR(22,20)	2	Input variable, stores the years (days) of specific output

Symbol	Location*	Definition
WURAT(22)	1	Annual net production g/m ² /year for specific plant
WUTP	1	Maximum yearly water utilization efficiency for photosynthesis ml/g CH ₂ O
WUYAW(22)	1	Net yearly productivity g/m ² /year
WYAV(22)	1	Cumulative net yearly productivity g/m ² /year by specific plant
W1	1	Input variable, wilting point of soil, % H ₂ O
W11	1	Potential leaf biomass, kg/m ²
W3	4	Animal weights, mature weight ratio
W5	4	Weight gain, kg
X(12)	1	Input variable, January through December monthly precipitation
X(60)	2	Total advantage factor for lth diameter class for biomass allocation
X(8,4)	4	Blood weight(kg) for kth population category; lth animal category
XHERB	1,4	Input variable, controls output in RMNANT Sub-routine on a daily basis. The value indicates the years when such output will occur (modulus)
XJ1(22)	2	Input variable, size of diameter class intervals (---etc. 2" - 0.2")
XPLNT	1	Input variable, year for daily output of plant simulation
XWRT	2	Switching constant for specific activity determination
X1	4	Per cent of fermented energy as fatty acids
X8(22)	1	Ratio of root specific activity to top 1" soil specific activity
Y	1	Random number
Y(8,4)	4	Inhalation rate m ³ /day for kth population category, lth animal category

Symbol	Location*	Definition
YRCNT(16)	1	Input variable, determines specific years for application of an acute event. The year may be sequential or nonsequential but equal to CYR
YRGRZ(4,32)	1,2,3,4	Input variable, varied year grazing intervals (5-50), (60-80), etc.
YRLY	1,2	Alphanumeric literal used for output purposes only
Y1	1	Input variable, activity of soil, activity/g dry weight in soil
Y2	1	Input variable, allocates a specific year to obtain daily output
Z(60)	2	Volume of average tree, ft ³ , in class diameter(l)
Z(8,4)	4	Population structure, fraction of total herd for kth population category; lth animal category
ZF(22,32)	1	Input variable, root fraction in given soil horizon
ZFLL	1	RFC
ZP	1	Activity/gram in soil, top 250 mm horizon
ZU(22,32)	1	Input variable, uptake coefficient for a radio-nuclide in a given soil horizon
Z1(2,32)	1,2,3,4	Input variable, soil activity, activity, gram dry weight
Z2(22)	1,2,3	Activity/m ² in live root of specific plant
Z3(22)	1,2,3,4	Activity/m ² in live above ground biomass of specific plant
Z4(22)	1,2,3,4	Activity/m ² in dead standing above ground biomass
Z4R(22)	1,2,3,4	Activity/m ² in dead standing root biomass
Z5(22)	1,2,3,4	Activity/m ² in litter-humus produced above ground
Z5R(22)	1	Activity/m ² in litter-humus produced below ground
Z6(22)	1	Activity/g in live root compartment
Z7(22)	1	Activity/g in live above ground biomass
Z7P	1	Activity/g in dead standing above ground biomass
Z7PR	1	Activity/g in dead standing root biomass

Symbol	Location*	Definition
Z77	1	Ratio of surface and internal specific activity to top 1" specific activity of soil
Z8(22)	1	Ratio of above ground specific activity to top 1" specific activity of soil
Z9(22)	1	Cumulative activity/m ³ in litter-humus produced above ground
Z9R(22)	1	Cumulative activity/m ³ in litter-humus produced below ground
Z99	2	Call statement, see Z9(l) in Main Program

LASL Identification

No. LP-711 BIOTRAN

PROGRAM PLANTS (INPUT,OUTPUT)	PLA	2
COMMON H1(22), CCVV(22), A1(22), A2(22), B1(22), R1(22), D1(22),	PLA	3
1 B5(22), Z3(22), Z4(22), Z5(22), VTMBR(22,60), RD1(22), V8(22),	PLA	4
2 TPGNH(22), HND(22), ZF(22,32), Z4R(22), RSCF(22), SFAC(22), C8(22),	PLA	5
3 Z1(22,32), CFAC(22)	PLA	6
COMMON YRGRZ(4,32), PUTZD(4,22), ROC(22), ICA(22), ACRES(22), CUTA	PLA	7
1 (22,8)	PLA	8
COMMON DTBR(22,60), AGTB(22,60), AATB(22,60), SATB(22,60), C8(22)	PLA	9
COMMON GTMBR(22,60), DATCT(22,32), TERM(22), SCTP(22), RINGT(22)	PLA	10
DIMENSION X(12), Q(24), NN(24), NDAY(12), EA(22), RIRRC(22)	PLA	11
DIMENSION E5(22), E7(22), WA(22), AWATA(22,16), DIRA(22,16)	PLA	12
DIMENSION ZU(22,32), ZF(22,32), AAA(22), B7(22), RH1(22), Z6(22)	PLA	13
DIMENSION Z7(22), Z8(22), Z9(22), Z5R(22), X8(22)	PLA	14
DIMENSION IRG(22), WYAV(22), MURAT(22), CXFAC(22)	PLA	15
DIMENSION TSP(22), TLA1(22), Z3R(22), RANK(22), STBR(22)	PLA	16
DIMENSION RSS(22), CVMX(22), RSB10(22), RCODE(22), S01LF(22)	PLA	17
DIMENSION YRCNT(16), DA1C(16), AMAC(16,64), RSUSP(22)	PLA	18
REAL M1, K2, K3, L1, L2, K4, L3	PLA	19
DATA (NDAY(1),1=1,12) /30,27,30,29,30,29,2*30,29,30,29,30/	PLA	20
DATA ANOT, BLANK, DLY, YRLY /3*NOT,3H ,6H DAILY ,3H YEARLY/	PLA	21
10 READ 1570, T1,T2,L1,T3,T4,L2	PLA	22
IF (T1.EQ.0.0) CALL EXIT	PLA	23
READ 1570, TRE,THXV,PRCV,RELV,ALPSR	PLA	24
NRE=TRE	PLA	25
READ 1570, (X(1),1=1,12)	PLA	26
READ 1570, R,G1,L3,F1,W1,H,Y1,Y2	PLA	27
READ 1570, RSCDE,RHERB,RANDN,FR'N,ARIG,AICHE,FRCT	PLA	28
IRIG=ARIG	PLA	29
NICHE=AICHE	PLA	30
READ 1570, (ROC(L),L=1,22)	PLA	31
READ 1570, (RIRRC(L),L=1,22)	PLA	32
READ 1570, (RSS(L),L=1,22)	PLA	33
READ 1570, (ACRES(L),L=1,22)	PLA	34
READ 1570, (RCODE(L),L=1,22)	PLA	35
READ 1570, CHRAC,CYR,DURC,CHRSY,CHREY,CHRSO,CHRED	PLA	36
IYR=CYR	PLA	37
IDUR=DURC	PLA	38
IF (IYR.EQ.0) GO TO 30	PLA	39
READ 1570, (YRCNT(K),K=1,IYR)	PLA	40
READ 1570, (DA1C(K),K=1,IYR)	PLA	41
DO 20 L=1,IYR	PLA	42
READ 1570, (AMAC(L,K),K=1,IDUR)	PLA	43
20 CONTINUE	PLA	44
30 CONTINUE	PLA	45
F1=F1*2.50	PLA	46
W1=W1*2.50	PLA	47
H=H*2.50	PLA	48
PLNTS=0.0	PLA	49
DO 50 K=1,22	PLA	50
AK=K	PLA	51
IF (ROC(K).GT.0.0) PLNTS=PLNTS+1.0	PLA	52
WA(K)=W1	PLA	53
RINGT(K)=0.0	PLA	54
E5(K)=0.0	PLA	55
E7(K)=0.0	PLA	56
EA(K)=0.0	PLA	57
RANK(K)=0.0	PLA	58
TERM(K)=0.1	PLA	59
DO 50 J=1,16	PLA	60
AWATA(K,J)=0.0	PLA	61
IF (J.GT.8) GO TO 40	PLA	62
CUTA(K,J)=0.0	PLA	63
DIRA(K,J)=0.0	PLA	64
40 CONTINUE	PLA	65

50 CONTINUE	PLA	66
READ 1570, FFP,SDPTH,UPTKE,XPLNT,XHERB	PLA	67
UPTKE=UPTKE*.1OE-09	PLA	68
DO 90 J=1,22	PLA	69
SOILF(J)=0.0	PLA	70
IF (RGC(J).EQ.0.0) GO TO 90	PLA	71
SOILF(J)=0.632/(1.0-EXP(-.004*SDPTH))	PLA	72
IF (RCODE(J).EQ.0.0) GO TO 60	PLA	73
SOILF(J)=0.632/(1.0-EXP(-.004*RCODE(J)))	PLA	74
IICDE=INT(RCODE(J)/250.0)+1.0	PLA	75
READ 1560, (Z1(J,L),L=1,IICDE)	PLA	76
READ 1560, (ZF(J,L),L=1,IICDE)	PLA	77
READ 1560, (ZU(J,L),L=1,IICDE)	PLA	78
GO TO 80	PLA	79
60 CONTINUE	PLA	80
RCODE(J)=INT(SDPTH/250.)*1.0	PLA	81
IICDE=RCODE(J)+1.0	PLA	82
RCODE(J)=RCODE(J)*250.0	PLA	83
ZF(J,1)=0.0	PLA	84
ZU(J,1)=0.0	PLA	85
Z1(J,1)=Y1	PLA	86
RFC=0.0	PLA	87
DO 70 L=2,IICDE	PLA	88
AL=L-1	PLA	89
Z1(J,L)=UPTKE	PLA	90
Z1(J,L)=Y1	PLA	91
ZFLL=.632/(1.-EXP(-.004*250.*AL))	PLA	92
ZFLL=1.0/ZFLL	PLA	93
SOILP=1.0/SOILF(L)	PLA	94
IF (ZFLL.GE.SOILP.AND.IICDE.EQ.2) ZFLL=SOILP	PLA	95
ZF(J,L)=(ZFLL-RFC)/SOILP	PLA	96
RFC=ZFLL	PLA	97
70 CONTINUE	PLA	98
RND0=10*INT(SDPTH/250.)	PLA	99
REEL=10.0*SDPTH/250.	PLA	100
DIFF=(REEL-RND0)/10.0	PLA	101
ZU(J,IICDE)=ZU(J,IICDE)*DIFF	PLA	102
80 CONTINUE	PLA	103
90 CONTINUE	PLA	104
F7=0.0	PLA	105
S1=41	PLA	106
P1=3.1416	PLA	107
DO 100 L=1,22	PLA	108
AAA(L)=0.0	PLA	109
CCVV(L)=0.0	PLA	110
A2(L)=0.0	PLA	111
D1(L)=1.	PLA	112
H1(L)=1.	PLA	113
B1(L)=1.	PLA	114
R1(L)=1.	PLA	115
RD1(L)=1.	PLA	116
RH1(L)=1.	PLA	117
A1(L)=0.	PLA	118
B5(L)=0.	PLA	119
B7(L)=0.	PLA	120
Z2(L)=0.	PLA	121
Z3(L)=0.	PLA	122
Z4(L)=0.	PLA	123
Z5(L)=0.	PLA	124
Z6(L)=0.	PLA	125
Z7(L)=0.	PLA	126
Z8(L)=0.	PLA	127
Z9(L)=0.	PLA	128
Z4R(L)=0.	PLA	129

ZSR(L)=0.	PLA	130
ZSR(L)=0.	PLA	131
WYAV(L)=0.	PLA	132
XB(L)=0.	PLA	133
STBR(L)=0.0	PLA	134
CXFAC(L)=0.0	PLA	135
SFAC(L)=1.0	PLA	136
CFAC(L)=1.0	PLA	137
CVMX(L)=1.0	PLA	138
CS(L)=1.0	PLA	139
VB(L)=1.0	PLA	140
CB(L)=1.0	PLA	141
100 CONTINUE	PLA	142
WUYAN=0.0	PLA	143
SYAV=0.0	PLA	144
SFFA=1.0	PLA	145
CVTOT=1.0	PLA	146
AITT=0.0	PLA	147
SFFP=210.0-FFP/2.0	PLA	148
EFFP=210.0+FFP/2.0	PLA	149
CXX	PLA	150
C CUTX=HARVESTING DATES,AMATX=AMT WATER APPLIED,DIRX=IRR. SCHEDULE	PLA	151
CXX	PLA	152
CXX	PLA	153
DO 110 L=1,22	PLA	154
IF (RIRRC(L).EQ.0.0) GO TO 110	PLA	155
READ 1570, (CUTA(L,K),K=1,8)	PLA	156
READ 1570, (AMATA(L,K),K=1,16)	PLA	157
READ 1570, (DIRA(L,K),K=1,16)	PLA	158
110 CONTINUE	PLA	159
CXX	PLA	160
17=RANDOM	PLA	161
A=(T2-T1)/2.0	PLA	162
B=(T4-T3)/2.0	PLA	163
TB=0.0	PLA	164
DO 120 I1=1,17	PLA	165
120 Y=RANDOM(2.0)	PLA	166
IJ=INT(Y2)	PLA	167
ICYR=1	PLA	168
DO 1550 I2=1,IJ	PLA	169
I1=I2	PLA	170
ICDY=1	PLA	171
A11=I1	PLA	172
IF (IYR.EQ.0) GO TO 130	PLA	173
IF (A11.EQ.YRCNT(ICYR)+1.0) ICYR=ICYR+1	PLA	174
IF (ICYR.GT.1YR) ICYR=1YR	PLA	175
130 I1=I1-1	PLA	176
IF (I1.NE.0) GO TO 170	PLA	177
PRINT 1580	PLA	178
PRINT 1590	PLA	179
PRINT 1600, IJ	PLA	180
IF (NICHE.EQ.0) PRINT 1610, ANOT	PLA	181
IF (NICHE.GT.0) PRINT 1610, BLANK	PLA	182
IF (RSCDE.EQ.0.0) PRINT 1620, ANOT	PLA	183
IF (RSCDE.GT.0.0) PRINT 1620, BLANK	PLA	184
IF (CYR.EQ.0.0) PRINT 1630, ANOT	PLA	185
IF (CYR.GT.0.0) PRINT 1630, BLANK	PLA	186
IF (IRIG.EQ.0) PRINT 1640, ANOT	PLA	187
IF (IRIG.GT.0) PRINT 1640, BLANK	PLA	188
IF (FRMN.EQ.0.0) PRINT 1650, ANOT	PLA	189
IF (FRMN.GT.0.0) PRINT 1650, BLANK	PLA	190
IF (FRCT.EQ.0.0) PRINT 1670, ANOT	PLA	191
IF (FRCT.GT.0.0) PRINT 1670, BLANK	PLA	192
IF (RHERB.EQ.0.0) PRINT 1680, ANOT	PLA	193

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      IF (RHERB.GT.0.0) PRINT 1690, BLANK
      PRINT 1690
      PRINT 1700
      PRINT 1710, TMKV,T1,T2,G1
      PRINT 1720
      PRINT 1730, T3,T4,L3
      PRINT 1740
      PRINT 1750
      PRINT 1760, R,PRCV,FFP,EFFP
      PRINT 1770
      PRINT 1780
      PRINT 1790, (X(I),I=1,12)
      PRINT 1800
      PRINT 1810, TRE
      PRINT 1820
      PRINT 1830
      PRINT 1840, F1,H,W1,Y1,SDPTH
      DO 140 J=1,22
      IF (RGC(J).EQ.0.0) GO TO 140
      PRINT 1850, J
      PRINT 1860, (Z1(J,L),L=1,11CDE)
      PRINT 1860
      PRINT 1880, (Z2(J,L),L=1,11CDE)
      PRINT 1870
      PRINT 1880, (Z3(J,L),L=1,11CDE)
140  CONTINUE
      IF (CYR.EQ.0.0) GO TO 150
      PRINT 1890
      PRINT 1900
      PRINT 1910, CHRAC,CYR,DURC,CHRSY,CHREY
      PRINT 1920
      PRINT 1930, CHRSD,CHRED
150  CONTINUE
      IF (IRIG.EQ.0) GO TO 170
      PRINT 1940
      DO 160 J=1,22
      IF (RIRRC(J).EQ.0.0) GO TO 160
      PRINT 1950, J,ACRES(J)
      PRINT 1960
      PRINT 1970, (DIRA(J,1),I=1,16)
      PRINT 1980
      PRINT 1970, (AWATA(J,1),I=1,16)
      PRINT 1990
      PRINT 2000, (CUTA(J,1),I=1,8)
160  CONTINUE
170  CONTINUE
      AQ=11
      K3=0
      P1=0.0
      TAV=0.0
      DO 180 L=1,22
      MURAT(L)=0.0
      IRG(L)=2
      ICA(L)=2
180  CONTINUE
      DO 1350 III=1,365
      AIII=111
      AIRCA=0.0
      IF (IYR.EQ.0) GO TO 190
      IF (A11.NE.YRCNT(ICYR)) GO TO 190
      IF (A111.LT.DAIC(ICYR)) GO TO 190
      IF (A111.GE.DAIC(ICYR)+DURC) GO TO 190
      AIRCA=AMAC(ICYR,ICDY)
      ICDY=ICDY+1

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190 IF (A11.LT.CHRSY.OR.A11.GT.CHREY) GO TO 200	PLA	258
IF (A111.LT.CHRSD.OR.A111.GT.CHRED) GO TO 200	PLA	258
AIRCA=AIRCA+AIRAC(CHRAC,A11,A111)	PLA	260
200 IF (111.EQ.1.OR.111.EQ.32.OR.111.EQ.60.OR.111.EQ.91.OR.111.EQ.121	PLA	261
1 .OR.111.EQ.152.OR.111.EQ.182.OR.111.EQ.213.OR.111.EQ.244.OR.111	PLA	262
2 .EQ.274.OR.111.EQ.305.OR.111.EQ.335) 210,280	PLA	263
210 M=0	PLA	264
I=12	PLA	265
IF (111.LE.334) I=11	PLA	266
IF (111.LE.304) I=10	PLA	267
IF (111.LE.273) I=9	PLA	268
IF (111.LE.243) I=8	PLA	269
IF (111.LE.212) I=7	PLA	270
IF (111.LE.181) I=6	PLA	271
IF (111.LE.151) I=5	PLA	272
IF (111.LE.120) I=4	PLA	273
IF (111.LE.90) I=3	PLA	274
IF (111.LE.59) I=2	PLA	275
IF (111.LE.31) I=1	PLA	276
DRHM=X(I)*R*25.4	PLA	277
220 QB=0	PLA	278
DO 230 L=1,NRE	PLA	279
Q(L)=0	PLA	280
230 CONTINUE	PLA	281
DO 240 L=1,NRE	PLA	282
Q(L)=RANDOM(2.)*NDAY(1)	PLA	283
Q(L+NRE)=RANDOM(3.)	PLA	284
QB=QB+Q(L+NRE)	PLA	285
ABC=Q(L)-INT(Q(L))	PLA	286
NN(L)=INT(Q(L))+1	PLA	287
IF (ABC.LT.0.5) NN(L)=INT(Q(L))	PLA	288
240 CONTINUE	PLA	289
DO 260 L=1,NRE	PLA	290
DO 250 KKK=1,NRE	PLA	291
IF (L.EQ.KKK) GO TO 250	PLA	292
IF (NN(L).EQ.NN(KKK)) GO TO 220	PLA	293
250 CONTINUE	PLA	294
260 CONTINUE	PLA	295
G4=0	PLA	296
G5=0	PLA	297
DO 270 L=1,12	PLA	298
G4=G4+RANDOM(4.0)	PLA	299
G5=G5+RANDOM(2.0)	PLA	300
270 CONTINUE	PLA	301
G4=G4-6	PLA	302
G5=G5-6	PLA	303
280 M=M+1	PLA	304
K3=K3+1	PLA	305
D=(K3-L1)/365.0	PLA	306
E=(K3-L2)/365.	PLA	307
F=K3/365.0	PLA	308
AKK=A*(SIN(D*2.0*PI))+1.0)+T1	PLA	309
IF (AKK.GT.450.) AKK=450.	PLA	310
M1=0.001*AKK	PLA	311
T=B*(SIN(E*2.*PI)+1.))+T3	PLA	312
T=T+(RELV-G1)*ALPSR+L3	PLA	313
T=(T-32)*5./9.	PLA	314
T=T+G4*THXV	PLA	315
IF (T.GT.0.) GO TO 290	PLA	316
T=0.0	PLA	317
290 P=0	PLA	318
TAV=TAV+T/365.	PLA	319
DO 300 L=1,NRE	PLA	320
O=L	PLA	321

IF (M.EQ.NN(L)) GO TO 310	PLA	322
300 CONTINUE	PLA	323
GO TO 320	PLA	324
310 N=O+NRE	PLA	325
P=Q(N)*DRM/QB	PLA	326
P=P+P*Q5*PRCV	PLA	327
320 P1=P1+P	PLA	328
IF (T.GT.0.0) GO TO 330	PLA	329
F7=F7+P	PLA	330
330 CONTINUE	PLA	331
SNM=1.128*T	PLA	332
IF (F7.LT.SNM) SNM=F7	PLA	333
F7=F7-SNM	PLA	334
E2=0.6+0.18*T	PLA	335
DO 1200 LPN=1,22	PLA	336
IF (RGC(LPN).EQ.0.0) GO TO 1200	PLA	337
IF (T.GT.0.0) WA(LPN)=WA(LPN)+P+SNM	PLA	338
AAA(LPN)=AIRCA+AAA(LPN)	PLA	339
CXXXXXXXXXXXXXXXXXXXXXIRRIGATION MODULEXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	PLA	340
IF (RIRRC(LPN).EQ.0.0) GO TO 340	PLA	341
IRGG=IRG(LPN)	PLA	342
IF (A111.NE.DIRA(LPN,IRGG)) GO TO 340	PLA	343
WA(LPN)=WA(LPN)+AWATA(LPN,IRGG)*25.4	PLA	344
P1=P1+AWATA(LPN,IRGG)*25.4	PLA	345
IRG(LPN)=IRG(LPN)+1	PLA	346
340 CONTINUE	PLA	347
CXXXXXXXXXXXXXXXXXXXXXWARM SEASON PLANTSXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	PLA	348
IF (WA(LPN).GT.H) WA(LPN)=H	PLA	349
EA(LPN)=E2*WA(LPN)/F1	PLA	350
IF (WA(LPN).LE.W1) EA(LPN)=0.0	PLA	351
IF (WA(LPN).GE.F1) EA(LPN)=E2	PLA	352
WA(LPN)=WA(LPN)-EA(LPN)*501LF(LPN)	PLA	353
IF (WA(LPN).LE.W1) EA(LPN)=WA(LPN)-W1+EA(LPN)	PLA	354
IF (WA(LPN).LE.W1) WA(LPN)=W1	PLA	355
S1=WA(LPN)	PLA	356
E4=EA(LPN)	PLA	357
ISTP=1	PLA	358
SCTP(LPN)=1.0	PLA	359
SAFP=5.	PLA	360
E5(LPN)=1.0-(T-25.0)**2/225.0	PLA	361
IF (T.GT.25.) E5(LPN)=1.0-(T-25.0)**2/81.0	PLA	362
IF (LPN.LE.10) GO TO 350	PLA	363
SAFP=3.	PLA	364
E5(LPN)=1-(T-18)**2/256	PLA	365
IF (T.LT.18.) E5(LPN)=1.0-(T-18.1)**2/169.	PLA	366
CXXXXXXXXXXXXXXXXXXXXXWARM SEASON PLANTSXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	PLA	367
350 GO TO (360,370,380,390,400,410,420,430,440,450,460,470,480,490,500	PLA	368
1,510,520,530,540,550,560), LPN	PLA	369
360 CONTINUE	PLA	370
C CORN AND SORGHUM	PLA	371
GO TO 570	PLA	372
370 CONTINUE	PLA	373
C ANNUAL VEGETABLES AND GRAINS	PLA	374
GO TO 570	PLA	375
380 CONTINUE	PLA	376
C PASTURE GRASSES	PLA	377
GO TO 570	PLA	378
390 CONTINUE	PLA	379
C FRUIT TREES	PLA	380
E5(LPN)=1.0-(T-21.0)**2/169.0	PLA	381
IF (T.LT.21.0) E5(LPN)=1-(T-21.0)**2/121.0	PLA	382
ISTP=0	PLA	383
SCTP(LPN)=0.0	PLA	384
GO TO 570	PLA	385

400	CONTINUE	PLA	385
C	PINYON-JUNIPER	PLA	387
	IF (T.LT.25.0) E5(LPN)=1.0-(T-25.0)**2/625.0	PLA	388
	SCTP(LPN)=0.0	PLA	389
	GO TO 570	PLA	390
410	CONTINUE	PLA	391
C	DECIDUOUS SHRUBS	PLA	392
	E5(LPN)=1.0-(T-21.0)**2/169.0	PLA	393
	IF (T.LT.21.0) E5(LPN)=1-(T-21.0)**2/121.0	PLA	394
	ISTP=0	PLA	395
	SCTP(LPN)=0.0	PLA	396
	GO TO 570	PLA	397
420	CONTINUE	PLA	398
C	ANNUAL GRASSES AND HERBS	PLA	399
	GO TO 570	PLA	400
430	CONTINUE	PLA	401
C	WARM SEASON GRASSES	PLA	402
	GO TO 570	PLA	403
440	CONTINUE	PLA	404
C	EVERGREEN SHRUBS	PLA	405
	E5(LPN)=1.0-(T-21.0)**2/169.0	PLA	406
	IF (T.LT.21.0) E5(LPN)=1-(T-21.0)**2/441.0	PLA	407
	SCTP(LPN)=0.0	PLA	408
	GO TO 570	PLA	409
450	CONTINUE	PLA	410
C	DECIDUOUS TREES	PLA	411
	E5(LPN)=1.0-(T-21.0)**2/169.0	PLA	412
	IF (T.LT.21.0) E5(LPN)=1-(T-21.0)**2/121.0	PLA	413
	ISTP=0	PLA	414
	SCTP(LPN)=0.0	PLA	415
	SAFP=3.0	PLA	416
	GO TO 570	PLA	417
	CXX	PLA	418
	CXXXXXXXXXXXXXXXXXXXX(COOL SEASON PLANTS)XXXXXXXXXXXXXXXXXXXXXXXXXXXX	PLA	419
460	CONTINUE	PLA	420
C	ALFALFA	PLA	421
	E5(LPN)=1.0-(T-21.0)**2/169.0	PLA	422
	IF (T.LT.21.0) E5(LPN)=1-(T-21.0)**2/121.0	PLA	423
	SAFP=4.0	PLA	424
	GO TO 570	PLA	425
470	CONTINUE	PLA	426
C	ANNUAL VEGETABLES AND GRAINS	PLA	427
	GO TO 570	PLA	428
480	CONTINUE	PLA	429
C	PASTURE GRASSES	PLA	430
	GO TO 570	PLA	431
490	CONTINUE	PLA	432
C	DOUGLAS FIR	PLA	433
	E5(LPN)=1-(T-14.0)**2/400.0	PLA	434
	IF (T.LT.14.0) E5(LPN)=1-(T-14.0)**2/196.0	PLA	435
	SCTP(LPN)=0.0	PLA	436
	GO TO 570	PLA	437
500	CONTINUE	PLA	438
C	PONDEROSA PINE	PLA	439
	IF (T.LT.18.0) E5(LPN)=1-(T-18.0)**2/324.0	PLA	440
	SCTP(LPN)=0.0	PLA	441
	GO TO 570	PLA	442
510	CONTINUE	PLA	443
C	DECIDUOUS SHRUBS	PLA	444
	E5(LPN)=1.0-(T-15.0)**2/100.0	PLA	445
	IF (T.GT.15.0) E5(LPN)=1.0-(T-15.0)**2/361.0	PLA	446
	ISTP=0	PLA	447
	SCTP(LPN)=0.0	PLA	448
	GO TO 570	PLA	449

520	CONTINUE	PLA	450
C	SPRUCE-FIR	PLA	451
	E5(LPN)=1-(T-12.0)**2/484.0	PLA	452
	IF (T.LT.12.0) E5(LPN)=1-(T-12.0)**2/144.0	PLA	453
	SCTP(LPN)=0.0	PLA	454
	GO TO 570	PLA	455
530	CONTINUE	PLA	456
C	COOL SEASON GRASS	PLA	457
	GO TO 570	PLA	458
540	CONTINUE	PLA	459
C	ANNUAL GRASSES AND HERBS	PLA	460
	GO TO 570	PLA	461
550	CONTINUE	PLA	462
C	EVERGREEN SHRUBS	PLA	463
	E5(LPN)=1.0-(T-15.0)**2/225.0	PLA	464
	IF (T.GT.15.0) E5(LPN)=1.0-(T-15.0)**2/361.0	PLA	465
	SCTP(LPN)=0.0	PLA	466
	GO TO 570	PLA	467
560	CONTINUE	PLA	468
C	DECIDUOUS TREES	PLA	469
	E5(LPN)=1.0-(T-15.0)**2/100.0	PLA	470
	IF (T.GT.15.0) E5(LPN)=1.0-(T-15.0)**2/361.0	PLA	471
	ISTP=0	PLA	472
	SCTP(LPN)=0.0	PLA	473
570	CONTINUE	PLA	474
	IF (E5(LPN).LT.0.0) E5(LPN)=0.0	PLA	475
	Q1=SAFF/(F1-W1)	PLA	476
	E7(LPN)=1.-EXP(-Q1*(S1-W1))+.01	PLA	477
	IF (E7(LPN).LT.0.0) E7(LPN)=0.0	PLA	478
	B11=B11(LPN)/1000.	PLA	479
	W1=0.928*B11*EXP(-3.11*B11)+0.072*B11	PLA	480
	ARP=0.0	PLA	481
	WUTP=350.	PLA	482
	STRANS=0.75	PLA	483
	RTRANS=0.25	PLA	484
	BAP=1.	PLA	485
	BCP=1.	PLA	486
	RFP=.01	PLA	487
	HF=30.	PLA	488
	RXPP=.161	PLA	489
	RAP=0.13	PLA	490
	PSEP=1.	PLA	491
	BP=W1*(1000.+Q1(LPN))	PLA	492
	IF (LPN.LE.10) GO TO 580	PLA	493
	RFP=0.03	PLA	494
	RXPP=0.12	PLA	495
	RAP=0.18	PLA	496
	C66=1.0	PLA	497
580	GO TO (590,600,610,620,640,660,680,690,700,720,740,750,760,770,790	PLA	498
	1,810,830,850,860,870,890), LPN	PLA	499
590	CONTINUE	PLA	500
C	CORN AND SORGHUM	PLA	501
	IF (A111.LT.DIRA(LPN,1).OR.A111.GT.CUTA(LPN,1)) BAP=0.0	PLA	502
	IF (A111.LT.DIRA(LPN,1)+15.0.OR.BAP.EQ.0.0) BCP=0.0	PLA	503
	HF=1.0	PLA	504
	PSEP=0.5	PLA	505
	GO TO 910	PLA	506
600	CONTINUE	PLA	507
C	ANNUAL VEGETABLES AND GRAINS	PLA	508
	IF (A111.LT.DIRA(LPN,1).OR.A111.GT.CUTA(LPN,1)) BAP=0.0	PLA	509
	IF (A111.LT.DIRA(LPN,1)+15.0.OR.BAP.EQ.0.0) BCP=0.0	PLA	510
	HF=1.0	PLA	511
	GO TO 910	PLA	512
610	CONTINUE	PLA	513

C	PASTURE GRASSES	PLA	514
	RTRANS=0.7	PLA	515
	STRANS=0.3	PLA	516
	GO TO 910	PLA	517
620	CONTINUE	PLA	518
C	FRUIT TREES	PLA	519
	IF (111.LE.0) GO TO 630	PLA	520
	IF (111.EQ.1) WNI=WNI(LPN)	PLA	521
	IF (WNI.GE.0.5*TPGNW(LPN)) WNI=TPGNW(LPN)*0.5	PLA	522
630	ARP=1.5*WNI*1000.	PLA	523
	IF (A111.LE.SFFP+1..OR.A111.GE.EFFP+1.) ARP=ARP-WNI*1000.	PLA	524
	IF (ARP.GT.B1(LPN)-WNI*1000.) ARP=B1(LPN)-WNI*1000.	PLA	525
	HF=150.0	PLA	526
	STRANS=0.85	PLA	527
	RTRANS=0.15	PLA	528
	BP=1000.*WNI	PLA	529
	WUTP=900.0	PLA	530
	GO TO 910	PLA	531
640	CONTINUE	PLA	532
C	PINYON-JUNIPER	PLA	533
	IF (111.LE.0) GO TO 650	PLA	534
	IF (111.EQ.1) WNI=WNI(LPN)	PLA	535
	IF (WNI.GE.TPGNW(LPN)) WNI=TPGNW(LPN)	PLA	536
650	ARP=5.0*WNI*1000.	PLA	537
	IF (ARP.GT.B1(LPN)-WNI*1000.) ARP=B1(LPN)-WNI*1000.	PLA	538
	VB(LPN)=2.54	PLA	539
	CB(LPN)=1.54	PLA	540
	HF=300.0	PLA	541
	STRANS=0.85	PLA	542
	RTRANS=0.15	PLA	543
	BP=1000.*WNI	PLA	544
	WUTP=725.0	PLA	545
	GO TO 910	PLA	546
660	CONTINUE	PLA	547
C	DECIDUOUS SHRUBS	PLA	548
	IF (111.LE.0) GO TO 670	PLA	549
	IF (111.EQ.1) WNI=WNI(LPN)	PLA	550
	IF (WNI.GE.0.5*TPGNW(LPN)) WNI=TPGNW(LPN)*0.5	PLA	551
670	ARP=2.*WNI*1000.	PLA	552
	IF (A111.LE.SFFP+1..OR.A111.GE.EFFP+1.) ARP=ARP-WNI*1000.	PLA	553
	IF (ARP.GT.B1(LPN)-WNI*1000.) ARP=B1(LPN)-WNI*1000.	PLA	554
	HF=70.0	PLA	555
	BP=1000.*WNI	PLA	556
	WUTP=900.0	PLA	557
	GO TO 910	PLA	558
680	CONTINUE	PLA	559
C	ANNUAL GRASSES AND HERBS	PLA	560
	RTRANS=0.5	PLA	561
	STRANS=0.5	PLA	562
	HF=1.0	PLA	563
	GO TO 910	PLA	564
690	CONTINUE	PLA	565
C	WARM SEASON GRASS	PLA	566
	RTRANS=0.7	PLA	567
	STRANS=0.3	PLA	568
	HF=30.0	PLA	569
	GO TO 910	PLA	570
700	CONTINUE	PLA	571
C	EVERGREEN SHRUBS	PLA	572
	IF (111.LE.0) GO TO 710	PLA	573
	IF (111.EQ.1) WNI=WNI(LPN)	PLA	574
	IF (WNI.GE.TPGNW(LPN)) WNI=TPGNW(LPN)	PLA	575
710	ARP=5.0*WNI*1000.	PLA	576
	IF (ARP.GT.B1(LPN)-WNI*1000.) ARP=B1(LPN)-WNI*1000.	PLA	577

HF=70.	PLA	578
BP=1000.*WN1	PLA	579
WUTP=725.0	PLA	580
GO TO 910	PLA	581
720 CONTINUE	PLA	582
C DECIDUOUS TREES	PLA	583
IF (111.LE.0) GO TO 730	PLA	584
IF (111.EQ.1) WN1=4ND(LPN)	PLA	585
IF (WN1.GE.0.5*TPGNW(LPN)) WN1=TPGNW(LPN)*0.5	PLA	586
730 ARP=1.5*WN1*1000.	PLA	587
IF (A111.LE.SFFP+1..OR.A111.GE.EFFP+1.) ARP=ARP-WN1*1000.	PLA	588
IF (ARP.GT.B1(LPN)-WN1*1000.) ARP=B1(LPN)-WN1*1000.	PLA	589
BP=1000.*WN1	PLA	590
STRANS=0.85	PLA	591
RTRANS=0.15	PLA	592
WUTP=900.0	PLA	593
HF=175.0	PLA	594
GO TO 910	PLA	595
740 CONTINUE	PLA	596
C ALFALFA	PLA	597
STRANS=0.5	PLA	598
RTRANS=0.5	PLA	599
RFP=.01	PLA	600
RQFP=.161	PLA	601
RAP=.13	PLA	602
GO TO 910	PLA	603
750 CONTINUE	PLA	604
C ANNUAL VEGETABLES AND GRAINS	PLA	605
IF (A111.LT.DIRA(LPN,1).OR.A111.GT.CUTA(LPN,1)) BAP=0.0	PLA	606
IF (A111.LT.DIRA(LPN,1)+15.0.OR.BAP.EQ.0.0) BCP=0.0	PLA	607
HF=1.0	PLA	608
GO TO 910	PLA	609
760 CONTINUE	PLA	610
C PASTURE GRASSES	PLA	611
RTRANS=0.7	PLA	612
STRANS=0.3	PLA	613
GO TO 910	PLA	614
770 CONTINUE	PLA	615
C DOUGLAS FIR	PLA	616
IF (111.LE.0) GO TO 780	PLA	617
IF (111.EQ.1) WN1=4ND(LPN)	PLA	618
IF (WN1.GE.TPGNW(LPN)) WN1=TPGNW(LPN)	PLA	619
780 ARP=2.0*WN1*1000.	PLA	620
IF (ARP.GT.B1(LPN)-WN1*1000.) ARP=B1(LPN)-WN1*1000.	PLA	621
STRANS=0.85	PLA	622
RTRANS=0.15	PLA	623
HF=310.	PLA	624
BP=WN1*1000.	PLA	625
WUTP=725.0	PLA	626
GO TO 910	PLA	627
790 CONTINUE	PLA	628
C PONDEROSA PINE	PLA	629
IF (111.LE.0) GO TO 800	PLA	630
IF (111.EQ.1) WN1=4ND(LPN)	PLA	631
IF (WN1.GE.TPGNW(LPN)) WN1=TPGNW(LPN)	PLA	632
800 ARP=3.*WN1*1000.	PLA	633
IF (ARP.GT.B1(LPN)-WN1*1000.) ARP=B1(LPN)-WN1*1000.	PLA	634
V8(LPN)=1.36	PLA	635
STRANS=0.85	PLA	636
RTRANS=0.15	PLA	637
HF=300.	PLA	638
BP=WN1*1000.	PLA	639
WUTP=725.0	PLA	640
RFP=.01	PLA	641

	RAP=0.20	PLA	642
	RAPP=0.153	PLA	643
	GO TO 910	PLA	644
810	CONTINUE	PLA	645
C	DECIDUOUS SHRUBS	PLA	646
	IF (11.LE.0) GO TO 820	PLA	647
	IF (111.EQ.1) WNI=WNI(LPN)	PLA	648
	IF (WNI.GE.0.5*TPGNW(LPN)) WNI=TPGNW(LPN)*0.5	PLA	649
820	ARP=2.0*WNI*1000.	PLA	650
	IF (A111.LE.SFFP+1..OR.A111.GE.EFFP+1.) ARP=ARP-WNI*1000.	PLA	651
	IF (ARP.GT.B1(LPN)-WNI*1000.) ARP=B1(LPN)-WNI*1000.	PLA	652
	HF=70.	PLA	653
	BP=WNI*1000.	PLA	654
	WUTP=900.0	PLA	655
	GO TO 910	PLA	656
830	CONTINUE	PLA	657
C	SPRUCE-FIR	PLA	658
	IF (11.LE.0) GO TO 840	PLA	659
	IF (111.EQ.1) WNI=WNI(LPN)	PLA	660
	IF (WNI.GE.TPGNW(LPN)) WNI=TPGNW(LPN)	PLA	661
840	ARP=3.*WNI*1000.	PLA	662
	IF (ARP.GT.B1(LPN)-WNI*1000.) ARP=B1(LPN)-WNI*1000.	PLA	663
	STRANS=0.85	PLA	664
	RTRANS=0.15	PLA	665
	HF=300.	PLA	666
	BP=WNI*1000.	PLA	667
	WUTP=725.0	PLA	668
	GO TO 910	PLA	669
850	CONTINUE	PLA	670
C	COOL SEASON GRASS	PLA	671
	RTRANS=0.7	PLA	672
	STRANS=0.3	PLA	673
	HF=30.0	PLA	674
	GO TO 910	PLA	675
860	CONTINUE	PLA	676
C	ANNUAL GRASSES AND HERBS	PLA	677
	RTRANS=0.5	PLA	678
	STRANS=0.5	PLA	679
	HF=1.	PLA	680
	GO TO 910	PLA	681
870	CONTINUE	PLA	682
C	EVERGREEN SHRUBS	PLA	683
	IF (11.LE.0) GO TO 880	PLA	684
	IF (111.EQ.1) WNI=WNI(LPN)	PLA	685
	IF (WNI.GE.TPGNW(LPN)) WNI=TPGNW(LPN)	PLA	686
880	ARP=3.*WNI*1000.	PLA	687
	IF (ARP.GT.B1(LPN)-WNI*1000.) ARP=B1(LPN)-WNI*1000.	PLA	688
	HF=70.	PLA	689
	BP=WNI*1000.	PLA	690
	WUTP=725.0	PLA	691
	GO TO 910	PLA	692
890	CONTINUE	PLA	693
C	DECIDUOUS TREES	PLA	694
	IF (11.LE.0) GO TO 900	PLA	695
	IF (111.EQ.1) WNI=WNI(LPN)	PLA	696
	IF (WNI.GE.0.5*TPGNW(LPN)) WNI=TPGNW(LPN)*0.5	PLA	697
900	ARP=1.5*WNI*1000.	PLA	698
	IF (ARP.GT.B1(LPN)-WNI*1000.) ARP=B1(LPN)-WNI*1000.	PLA	699
	IF (A111.LE.SFFP+1..OR.A111.GE.EFFP+1.) ARP=ARP-WNI*1000.	PLA	700
	IF (ARP.GT.B1(LPN)+R1(LPN)) ARP=B1(LPN)+R1(LPN)	PLA	701
	STRANS=0.85	PLA	702
	RTRANS=0.15	PLA	703
	BP=WNI*1000.	PLA	704
	HF=175.	PLA	705

WUTP=900.0	PLA	706
910 CONTINUE	PLA	707
AC=.3*RFP*EXP(RXPP*T)*RAP	PLA	708
AC=AC*SFAC(LPN)*CFAC(LPN)	PLA	709
WNI=WNI*1000.0	PLA	710
TLA1(LPN)=0.013*BP	PLA	711
RSB10(LPN)=ARP	PLA	712
IF (ARP.EQ.0.0) RSB10(LPN)=WNI	PLA	713
PSE=PSEP	PLA	714
IF (RSCDE.EQ.0.0) SFAC(LPN)=1.0	PLA	715
IF (RSS(LPN).GT.12.) SFAC(LPN)=1.0	PLA	716
IF (RSCDE.GT.0.0.AND.11.LE.0) SFAC(LPN)=(30./HF)/RSCDE	PLA	717
IF (ISTP.EQ.1) GO TO 920	PLA	718
IF (A111.GT.SFFP+1.A.A111.LT.EFFP+1) GO TO 920	PLA	719
WNI=1.0	PLA	720
920 B5(LPN)=WNI*BAP*M1*E5(LPN)*E7(LPN)	PLA	721
B5(LPN)=B5(LPN)-(WNI+ARP)*RFP*EXP(RXPP*T)*RAP*BCP	PLA	722
B5(LPN)=B5(LPN)*CFAC(LPN)*SFAC(LPN)	PLA	723
T5=E4*1000	PLA	724
T5=T5*CFAC(LPN)*SFAC(LPN)	PLA	725
WNI(LPN)=WNI	PLA	726
T5P(LPN)=T5	PLA	727
C=E5(LPN)*E7(LPN)	PLA	728
IF (C.LE.0.01) C=0.01	PLA	729
C=WUTP/C	PLA	730
C=C*PSE	PLA	731
T6=C*B5(LPN)	PLA	732
EWAT=B5(LPN)	PLA	733
IF (T6.GT.T5) EWAT=(T5/T6)*B5(LPN)	PLA	734
IF (B5(LPN).LE.0.0) EWAT=B5(LPN)	PLA	735
WURAT(LPN)=WURAT(LPN)+EWAT	PLA	736
B5(LPN)=EWAT	PLA	737
B7(LPN)=RTRANS*B5(LPN)	PLA	738
B5(LPN)=B5(LPN)*STRANS	PLA	739
IF (B5(LPN).GE.0.0) GO TO 930	PLA	740
B5(LPN)=B5(LPN)/STRANS	PLA	741
B7(LPN)=B5(LPN)*R1(LPN)/(B1(LPN)+R1(LPN))	PLA	742
B5(LPN)=B5(LPN)-B7(LPN)	PLA	743
930 CONTINUE	PLA	744
CXX	PLA	745
B1(LPN)=B1(LPN)+B5(LPN)	PLA	746
R1(LPN)=R1(LPN)+B7(LPN)	PLA	747
RSCF(LPN)=HF	PLA	748
AP=2./(365.*HF)	PLA	749
GO TO (940,960,980,990,1000,1010,1020,1030,1040,1050,1060,1070,109	PLA	750
1 0,1100,1110,1120,1130,1140,1150,1160,1170), LPN	PLA	751
CXXXXXXXXXXXXXXXXXXXXARM SEASON PLANTSXXXXXXXXXXXXXXXXXXXXXXXX	PLA	752
940 CONTINUE	PLA	753
C CORN AND SORGHUM	PLA	754
D3=.005*B1(LPN)	PLA	755
IF (T.GT.25.) D3=B1(LPN)*(.05*(T-25.)+.10)*.05	PLA	756
IF (T.LT.10.) D3=B1(LPN)*(1.1-.1*T)*.05	PLA	757
RD3=D3*R1(LPN)/B1(LPN)	PLA	758
IF (A111.NE.CUTA(LPN,1)) GO TO 950	PLA	759
Z4(LPN)=Z4(LPN)+0.1*Z3(LPN)	PLA	760
Z3(LPN)=0.0	PLA	761
D3=B1(LPN)*0.1	PLA	762
Z4R(LPN)=Z4R(LPN)+Z2(LPN)	PLA	763
Z2(LPN)=0.0	PLA	764
RD3=R1(LPN)	PLA	765
950 IF (A111.GE.DIRA(LPN,1).AND.A111.LE.CUTA(LPN,1)) GO TO 1180	PLA	766
B1(LPN)=1.	PLA	767
R1(LPN)=1.	PLA	768
B5(LPN)=0.0	PLA	769

D3=0.	FLA	770
GO TO 1180	FLA	771
960 CONTINUE	FLA	772
C ANNUAL VEGETABLES AND GRAINS	FLA	773
D3=.005*B1(LPN)	FLA	774
IF (T.LT.10.0) D3=B1(LPN)*(1.1-.1*T)*.05	FLA	775
IF (T.GT.25.0) D3=B1(LPN)*(.05*(T-25.)+.10)*.05	FLA	776
RD3=D3*R1(LPN)/B1(LPN)	FLA	777
IF (A111.NE.CUTA(LPN,1)) GO TO 970	FLA	778
Z4(LPN)=Z4(LPN)+0.1*Z3(LPN)	FLA	779
Z3(LPN)=0.0	FLA	780
D3=B1(LPN)*0.1	FLA	781
Z4R(LPN)=Z4R(LPN)+Z2(LPN)	FLA	782
Z2(LPN)=0.0	FLA	783
RD3=R1(LPN)	FLA	784
970 IF (A111.GE.DIRA(LPN,1).AND.A111.LE.CUTA(LPN,3)) GO TO 1180	FLA	785
B1(LPN)=1.	FLA	786
R1(LPN)=1.	FLA	787
B5(LPN)=0.0	FLA	788
D3=0.	FLA	789
GO TO 1180	FLA	790
980 CONTINUE	FLA	791
C PASTURE GRASSES	FLA	792
D3=B1(LPN)*.005	FLA	793
IF (T.LT.10.0) D3=B1(LPN)*(1.1-.1*T)*.05	FLA	794
IF (T.GT.25.0) D3=B1(LPN)*(.10*(T-25.)+.10)*.05	FLA	795
R1(LPN)=R1(LPN)-AC*R1(LPN)	FLA	796
RD3=R1(LPN)*AP	FLA	797
ICAAA=ICA(LPN)	FLA	798
IF (A111.NE.CUTA(LPN,ICAAA)) GO TO 1180	FLA	799
ICA(LPN)=ICA(LPN)+1	FLA	800
IF (B1(LPN).LE.20.0) GO TO 1180	FLA	801
Z3(LPN)=Z3(LPN)*20./B1(LPN)	FLA	802
Z4(LPN)=(20./B1(LPN))*Z4(LPN)	FLA	803
D1(LPN)=D1(LPN)*(20./B1(LPN))	FLA	804
B1(LPN)=20.	FLA	805
GO TO 1180	FLA	806
990 CONTINUE	FLA	807
C FRUIT TREES	FLA	808
D3=B1(LPN)*AP	FLA	809
IF (A111.EQ.EFFP) D3=HNI+B1(LPN)*AP	FLA	810
RD3=D3*R1(LPN)/B1(LPN)	FLA	811
GO TO 1180	FLA	812
1000 CONTINUE	FLA	813
C PINYON-JUNIPER	FLA	814
D3=0.693*HNI/(2.*365.)*B1(LPN)*AP	FLA	815
RD3=D3*R1(LPN)/B1(LPN)	FLA	816
RSCF(LPN)=150.	FLA	817
GO TO 1180	FLA	818
1010 CONTINUE	FLA	819
C DECIDUOUS SHRUBS	FLA	820
D3=B1(LPN)*AP	FLA	821
IF (A111.EQ.EFFP) D3=HNI+B1(LPN)*AP	FLA	822
RD3=D3*R1(LPN)/B1(LPN)	FLA	823
GO TO 1180	FLA	824
1020 CONTINUE	FLA	825
C ANNUAL GRASSES AND HERBS	FLA	826
D3=.005*B1(LPN)	FLA	827
IF (T.LT.10.0) D3=B1(LPN)*(1.1-.1*T)*.05*2.0	FLA	828
IF (T.GT.25.0) D3=B1(LPN)*(.10*(T-25.0)+.10)*.05*2.	FLA	829
RD3=D3*(R1(LPN)/B1(LPN))+R1(LPN)*AP	FLA	830
RSCF(LPN)=9.0	FLA	831
GO TO 1180	FLA	832
1030 CONTINUE	FLA	833

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Z4(LPN)=Z4(LPN)*(20./B1(LPN))	PLA	888
D1(LPN)=D1(LPN)*(20./B1(LPN))	PLA	889
B1(LPN)=20.	PLA	900
GO TO 1180	PLA	901
1100 CONTINUE	PLA	902
C DOUGLAS FIR	PLA	903
D3=0.693*WNI/(2.*365.)*B1(LPN)*AP	PLA	904
RD3=D3*R1(LPN)/B1(LPN)	PLA	905
GO TO 1180	PLA	906
1110 CONTINUE	PLA	907
C PONDEROSA PINE	PLA	908
D3=0.693*WNI/(2.*365.)*B1(LPN)*AP	PLA	909
RD3=D3*R1(LPN)/B1(LPN)	PLA	910
RSCF(LPN)=150.	PLA	911
GO TO 1180	PLA	912
1120 CONTINUE	PLA	913
C DECIDUOUS SHRUBS	PLA	914
D3=B1(LPN)*AP	PLA	915
IF (A111.EQ.EFFP) D3=WNI+B1(LPN)*AP	PLA	916
RD3=D3*R1(LPN)/B1(LPN)	PLA	917
GO TO 1180	PLA	918
1130 CONTINUE	PLA	919
C SPRUCE-FIR	PLA	920
D3=0.693*WNI/(2.*365.)*B1(LPN)*AP	PLA	921
RD3=D3*R1(LPN)/B1(LPN)	PLA	922
GO TO 1180	PLA	923
1140 CONTINUE	PLA	924
C COOL SEASON GRASS	PLA	925
D3=.005*B1(LPN)	PLA	926
IF (T.LT.5.0) D3=B1(LPN)*(1.1-.2*T)*.05	PLA	927
IF (T.GT.18.0) D3=B1(LPN)*(.10*(T-18.))+.10)*.05	PLA	928
R1(LPN)=R1(LPN)-AC*R1(LPN)	PLA	929
RD3=R1(LPN)*AP	PLA	930
GO TO 1180	PLA	931
1150 CONTINUE	PLA	932
C ANNUAL GRASSES AND HERBS	PLA	933
D3=.005*B1(LPN)	PLA	934
IF (T.LT.5.0) D3=B1(LPN)*(1.1-.2*T)*.05*2.	PLA	935
IF (T.GT.18.0) D3=B1(LPN)*(.10*(T-18.))+.10)*.05*2.	PLA	936
RD3=D3*R1(LPN)/B1(LPN)+R1(LPN)*AP	PLA	937
RSCF(LPN)=9.0	PLA	938
GO TO 1180	PLA	939
1.60 CONTINUE	PLA	940
C EVERGREEN SHRUBS	PLA	941
D3=0.693*WNI/(1.*365.)*B1(LPN)*AP	PLA	942
RD3=D3*R1(LPN)/B1(LPN)	PLA	943
GO TO 1180	PLA	944
1170 CONTINUE	PLA	945
C DECIDUOUS TREES	PLA	946
D3=B1(LPN)*AP	PLA	947
IF (A111.EQ.EFFP) D3=WNI+B1(LPN)*AP	PLA	948
RD3=D3*R1(LPN)/B1(LPN)	PLA	949
1180 CONTINUE	PLA	950
IF (B1(LPN)-D3.LE.1.0) D3=0.0	PLA	951
IF (R1(LPN)-RD3.LE.1.0) RD3=0.	PLA	952
B1(LPN)=B1(LPN)-D3	PLA	953
R1(LPN)=R1(LPN)-RD3	PLA	954
D1(LPN)=D1(LPN)+D3	PLA	955
RD1(LPN)=RD1(LPN)+RD3	PLA	956
CXX	PLA	957
CXX	PLA	958
H2=.004+.0032*T	PLA	959
H3=1.0+(1.0/(F1-H1))*(HA(LPN)-H1)	PLA	960
H1(LPN)=H1(LPN)+H2+H3*D1(LPN)	PLA	961

RHI(LPN)=RHI(LPN)+2*H3*RD1(LPN)	PLA	962
D1(LPN)=D1(LPN)+2*H3*D1(LPN)	PLA	963
RD1(LPN)=RD1(LPN)+2*H3*RD1(LPN)	PLA	964
HI(LPN)=HI(LPN)-AC*HI(LPN)	PLA	965
RHI(LPN)=RHI(LPN)-AC*RHI(LPN)	PLA	966
IF (B1(LPN).LE.1.0) B1(LPN)=1.0	PLA	967
IF (R1(LPN).LE.1.0) R1(LPN)=1.0	PLA	968
IF (D1(LPN).LE.1.0) D1(LPN)=1.0	PLA	969
IF (RD1(LPN).LE.1.0) RD1(LPN)=1.0	PLA	970
IF (HI(LPN).LE.1.0) HI(LPN)=1.0	PLA	971
IF (RHI(LPN).LE.1.0) RHI(LPN)=1.0	PLA	972
IF (I1.EQ.0.0) GO TO 1190	PLA	973
IF (ROC(LPN).NE.3.0) GO TO 1190	PLA	974
IF (B1(LPN).LE.1.0) GO TO 1190	PLA	975
IF (I1.NE.XPLNT) GO TO 1190	PLA	976
CALL FORMAN (I11,LPN,Z9(LPN),AAA(LPN))	PLA	977
1190 CONTINUE	PLA	978
1200 CONTINUE	PLA	979
IF (RHERB.EQ.1.0) CALL RMNANT (I1,I11,AITT,XHERB)	PLA	980
IF (NICHE.EQ.0) GO TO 1240	PLA	981
CXX	PLA	982
DO 1220 K=1,22	PLA	983
CFAC(K)=1.0	PLA	984
IF (RSS(K).EQ.0.0) GO TO 1220	PLA	985
IF (B5(K).LE.0.0) GO TO 1220	PLA	986
CFAC(K)=(B5(K)+B7(K))*C6(K)/(RSCF(K)*WIND(K))	PLA	987
CXFAC(K)=CFAC(K)	PLA	988
DO 1210 L=1,22	PLA	989
IF (RSS(L).EQ.0.0.OR.K.EQ.L) GO TO 1210	PLA	990
IF (B5(L).LE.0.0) GO TO 1210	PLA	991
IF (RSS(L).NE.RSS(K)) GO TO 1210	PLA	992
CFAC(K)=CFAC(K)+(B5(L)+B7(L))*C6(L)/(RSCF(L)*WIND(L))	PLA	993
1210 CONTINUE	PLA	994
1220 CONTINUE	PLA	995
DO 1230 K=1,22	PLA	996
IF (RSS(K).EQ.0.0) GO TO 1230	PLA	997
IF (B5(K).LE.0.0) GO TO 1230	PLA	998
CFAC(K)=CXFAC(K)/CFAC(K)	PLA	999
1230 CONTINUE	PLA	1000
CXX	PLA	1001
1240 CONTINUE	PLA	1002
CVTT=0.0	PLA	1003
AITT=0.0	PLA	1004
DO 1250 L=1,22	PLA	1005
IF (RGC(L).EQ.0.0) GO TO 1250	PLA	1006
IF (RSCDE.EQ.0.0) GO TO 1250	PLA	1007
CVTT=CVTT+CCVV(L)*CVMX(L)	PLA	1008
AITT=AITT+A1(L)*CVMX(L)	PLA	1009
1250 CONTINUE	PLA	1010
IF (CVTT.GT.1.0) CVTT=1.0	PLA	1011
RSUSP(LPN)=2.5*EXP(-4.6*CVTT)*1.E-08	PLA	1012
1260 DO 1310 LPN=1,22	PLA	1013
IF (RGC(LPN).EQ.0.0) GO TO 1310	PLA	1014
RSUSP(LPN)=2.5*EXP(-4.6*CVTT)*1.0E-08	PLA	1015
IF (CVTT.NE.0.0) GO TO 1270	PLA	1016
AITT=A1(LPN)	PLA	1017
CVTT=CCVV(LPN)	PLA	1018
RSUSP(LPN)=2.5*EXP(-4.6*CVTT)*1.E-08	PLA	1019
1270 CONTINUE	PLA	1020
IF (P.GT.0.0) GO TO 1280	PLA	1021
Z1(LPN,1)=Z1(LPN,1)-RSUSP(LPN)*Z1(LPN,1)-(.693/700.)*Z1(LPN,1)	PLA	1022
Z1(LPN,1)=Z1(LPN,1)+.0021*AITT*(1.0-CVTT)/3.0E04	PLA	1023
Z1(LPN,2)=Z1(LPN,2)+(.693/700.)*Z1(LPN,1)+3.0E04/3.75E05	PLA	1024
A1Z=RSUSP(LPN)*Z1(LPN,1)+3.0E04	PLA	1025

Z1(LPN,1)=Z1(LPN,1)+(.693/30.) *A2(LPN)/3.0E04+AC*Z5(LPN)/3.0E04	PLA	1026
A1(LPN)=RSUSP(LPN)*(A2(LPN)+Z5(LPN))+A1Z	PLA	1027
IF (AAA(LPN).GT.0.0) A1(LPN)=A1(LPN)+AAA(LPN)	PLA	1028
AAA(LPN)=0.0	PLA	1029
A2(LPN)=A2(LPN)-RSUSP(LPN)*A2(LPN)-.693*A2(LPN)/30.	PLA	1030
A2(LPN)=A2(LPN)+.0021*A1TT*TLA1(LPN)*CVTT*.67	PLA	1031
GO TO 1290	PLA	1032
1290 A1(LPN)=0.0	PLA	1033
Z1(LPN,1)=Z1(LPN,1)+.3*A2(LPN)*(1.-EXP(-.6518*P))/3.E04	PLA	1034
Z1(LPN,1)=Z1(LPN,1)-0.01*(1.-EXP(-.6518*P))*Z1(LPN,1)	PLA	1035
Z1(LPN,1)=Z1(LPN,1)+.7*A1TT*(1.-EXP(-.6518*P))*(1.-CVTT)/3.0E04	PLA	1036
Z1(LPN,2)=Z1(LPN,2)+.01*(1.-EXP(-.6518*P))*Z1(LPN,1)*3.E04/3.75E05	PLA	1037
A2(LPN)=A2(LPN)-.3*A2(LPN)*(1.-EXP(-.6518*P))	PLA	1038
A2(LPN)=A2(LPN)+.7*A1TT*(1.-EXP(-.6518*P))*CVTT*TLA1(LPN)	PLA	1039
1290 CONTINUE	PLA	1040
A11P=(A11-1.)*365.+A111	PLA	1041
IF (RSCF(LPN).LE.9.0) A11P=A111	PLA	1042
RPNTP=(1.-EXP(-.0001*A11P))*9144.	PLA	1043
11CDE=INT(RCODE(LPN)/250.0)+1.0	PLA	1044
DO 1300 L=2,11CDE	PLA	1045
AL=L-2	PLA	1046
SP=1.0	PLA	1047
IF (RPNTP.LT.AL*250.) SP=0.0	PLA	1048
RGAIN=ZU(LPN,L)*ZF(LPN,L)*TSP(LPN)*WHD(LPN)*Z1(LPN,L)*SP	PLA	1049
Z2(LPN)=Z2(LPN)+RGAIN	PLA	1050
Z1(LPN,L)=Z1(LPN,L)+ZF(LPN,L)*AC*ZSR(LPN)/3.75E05-RGAIN/3.75E05	PLA	1051
1300 CONTINUE	PLA	1052
H3=1.0+(1.0/(F1-W1))*(WA(LPN)-W1)	PLA	1053
ZP=1.	PLA	1054
IF (Z1(LPN,2).GT.0.0) ZP=Z1(LPN,2)	PLA	1055
B7(LPN)=ABS(B7(LPN))	PLA	1056
IF (B7(LPN).GT.RSB10(LPN)-1.0) B7(LPN)=RSB10(LPN)	PLA	1057
B111=B1(LPN)	PLA	1058
R111=R1(LPN)	PLA	1059
T111=RSB10(LPN)+WHD(LPN)	PLA	1060
ADD=(B7(LPN)/T111)*(1.-B7(LPN)/T111)	PLA	1061
IF (B1(LPN).LE.1.) ADD=0.0	PLA	1062
Z2LPN=Z2(LPN)	PLA	1063
Z3LPN=Z3(LPN)	PLA	1064
Z2(LPN)=Z2(LPN)-ADD*Z2(LPN)*B111/(B111+R111)	PLA	1065
Z2(LPN)=Z2(LPN)+ADD*Z3(LPN)*R111/(B111+R111)	PLA	1066
Z3(LPN)=Z3(LPN)+ADD*Z2(LPN)*B111/(B111+R111)	PLA	1067
Z3(LPN)=Z3(LPN)-ADD*Z3(LPN)*R111/(B111+R111)	PLA	1068
Z2LPN=Z2(LPN)	PLA	1069
Z3LPN=Z3(LPN)	PLA	1070
Z3(LPN)=Z3(LPN)-Z3(LPN)*D3/B1(LPN)	PLA	1071
Z2(LPN)=Z2(LPN)-Z2(LPN)*RD3/R1(LPN)	PLA	1072
IF (Z2(LPN).LT.0.0) Z2(LPN)=0.0	PLA	1073
IF (Z3(LPN).LT.0.0) Z3(LPN)=0.0	PLA	1074
Z4LPN=Z4(LPN)	PLA	1075
Z4RLPN=Z4R(LPN)	PLA	1076
Z5LPN=Z5(LPN)	PLA	1077
Z5RLPN=Z5R(LPN)	PLA	1078
Z4(LPN)=Z4(LPN)+Z3(LPN)*D3/B1(LPN)+H2*H3*Z4(LPN)	PLA	1079
Z4R(LPN)=Z4R(LPN)+Z2(LPN)*RD3/R1(LPN)+H2*H3*Z4R(LPN)	PLA	1080
Z9(LPN)=Z9(LPN)+AC*Z5(LPN)	PLA	1081
Z9R(LPN)=Z9R(LPN)+AC*Z5R(LPN)	PLA	1082
Z5(LPN)=Z5(LPN)+H2*H3*Z4(LPN)-AC*Z5(LPN)-RSUSP(LPN)*Z5(LPN)	PLA	1083
Z5R(LPN)=Z5R(LPN)+H2*H3*Z4R(LPN)-AC*Z5R(LPN)	PLA	1084
Z6(LPN)=Z2(LPN)/R1(LPN)	PLA	1085
X8(LPN)=Z6(LPN)/ZP	PLA	1086
Z7(LPN)=Z3(LPN)/B1(LPN)	PLA	1087
Z8(LPN)=Z7(LPN)/ZP	PLA	1088
T8=K3+365*11	PLA	1089

1310 CONTINUE	PLA	1090
IF (AQ.NE.XPLNT) GO TO 1350	PLA	1091
PRINT 2010, A11	PLA	1092
PRINT 2020	PLA	1093
DO 1320 LPN=1,22	PLA	1094
IF (ROC(LPN).EQ.0.0) GO TO 1320	PLA	1095
PRINT 2030, B1(LPN),R1(LPN),D1(LPN),H1(LPN),RD1(LPN),RH1(LPN),T,P	PLA	1096
1 ,A1(LPN),ZP,T5,A111,LPN	PLA	1097
1320 CONTINUE	PLA	1098
PRINT 2040	PLA	1099
DO 1330 LPN=1,22	PLA	1100
IF (ROC(LPN).EQ.0.0) GO TO 1330	PLA	1101
PRINT 2030, A2(LPN),Z2(LPN),Z3(LPN),Z4(LPN),Z4R(LPN),Z5(LPN),Z5R	PLA	1102
1 (LPN),Z6(LPN),Z7(LPN),Z8(LPN),Z9(LPN),Z9R(LPN),LPN	PLA	1103
1330 CONTINUE	PLA	1104
PRINT 2070	PLA	1105
DO 1340 LPN=1,22	PLA	1106
IF (ROC(LPN).EQ.0.0) GO TO 1340	PLA	1107
Z7P=0.0	PLA	1108
Z7PR=0.0	PLA	1109
IF (D1(LPN).GT.0.0) Z7P=Z4(LPN)/D1(LPN)	PLA	1110
IF (RD1(LPN).GT.0.0) Z7PR=Z4R(LPN)/RD1(LPN)	PLA	1111
A22=A2(LPN)/BP	PLA	1112
A23=A22/ZP	PLA	1113
Z77=(Z7(LPN)+A2(LPN)/B1(LPN))/ZP	PLA	1114
PRINT 2030, Z77,Z7P,Z7PR,X8(LPN),A22,A23,Z1(LPN,1),Z1(LPN,2),CFAC	PLA	1115
1 (LPN),SFAC(LPN),LPN	PLA	1116
1340 CONTINUE	PLA	1117
1350 CONTINUE	PLA	1118
SYAV=SYAV+1.0	PLA	1119
DO 1360 LPN=1,22	PLA	1120
IF (ROC(LPN).EQ.0.0) GO TO 1360	PLA	1121
WND(LPN)=WND(LPN)/1000.	PLA	1122
B11=B1(LPN)/1000.	PLA	1123
W11=.928*EXP(-3.11*B11)+.072*B11	PLA	1124
WUYAW=WURAT(LPN)/1000.	PLA	1125
IF (W11.LT.WUYAW.AND.SCTP(LPN).EQ.0.0) WUYAW=W11	PLA	1126
WYAV(LPN)=WYAV(LPN)+WUYAW	PLA	1127
TPGNH(LPN)=WYAV(LPN)/SYAV	PLA	1128
IF (TPGNH(LPN).LT.0.001) TPGNH(LPN)=0.001	PLA	1129
CCCC=(1.-EXP(-1.5*TPGNH(LPN)))*CS(LPN)	PLA	1130
IF (CCCC.GT.CCVV(LPN).AND.ROC(LPN).EQ.2.0) CCVV(LPN)=CCCC	PLA	1131
IF (CB(LPN).EQ.1.0) CCVV(LPN)=CCCC	PLA	1132
1360 CONTINUE	PLA	1133
C XXXXXXXXXXXXXXXXXXXX SUCCESSION MODULE XXXXXXXXXXXXXXXXXXXXXXXXXXXX	PLA	1134
SFFC=1.0	PLA	1135
IF (RSCDE.EQ.0.0) GO TO 1490	PLA	1136
DO 1370 K=1,22	PLA	1137
IF (ROC(K).EQ.0.0) GO TO 1370	PLA	1138
IF (RSS(K).GT.12.) GO TO 1370	PLA	1139
RANK(K)=1.0	PLA	1140
STBR(K)=STBR(K)*AQ	PLA	1141
STBR(K)=STBR(K)+(B1(K)+R1(K))/RSCF(K)	PLA	1142
STBR(K)=STBR(K)+(D1(K)+RD1(K)+H1(K)+RH1(K))/RSCF(K)	PLA	1143
STBR(K)=STBR(K)/(AQ+1.0)	PLA	1144
CVHX(K)=STBR(K)	PLA	1145
ACRES(K)=CCVV(K)	PLA	1146
1370 CONTINUE	PLA	1147
DO 1380 L=1,22	PLA	1148
IF (RANK(L).EQ.0.0.OR.RSS(L).EQ.0.0) GO TO 1390	PLA	1149
COV1=CCVV(L)*(B1(L)+R1(L))	PLA	1150
COV1=B1(L)+R1(L)	PLA	1151
DO 1380 K=1,22	PLA	1152
IF (RANK(K).EQ.0.0.OR.RSS(K).EQ.0.0) GO TO 1380	PLA	1153

IF (RSS(K).NE.RSS(L)) GO TO 1380	PLA	1154
IF (K.EQ.L) GO TO 1380	PLA	1155
STBR(L)=STBR(L)+STBR(K)	PLA	1156
COV1=COV1+CCVV(K)*(B1(K)+R1(K))	PLA	1157
COVT=COVT+(B1(K)+R1(K))	PLA	1158
RANK(K)=0.0	PLA	1159
1380 CONTINUE	PLA	1160
CCVV(L)=COV1/COVT	PLA	1161
IF (CCVV(L).GT.1.0) CCVV(L)=1.0	PLA	1162
1390 CONTINUE	PLA	1163
DO 1410 L=1,22	PLA	1164
IF (RGC(L).EQ.0.0) GO TO 1410	PLA	1165
IF (RANK(L).EQ.0.0) GO TO 1410	PLA	1166
DO 1400 K=1,22	PLA	1167
IF (RGC(K).EQ.0.0) GO TO 1400	PLA	1168
IF (RANK(K).EQ.0.0) GO TO 1400	PLA	1169
IF (STBR(K).LT.STBR(L)) RANK(K)=RANK(K)+1.0	PLA	1170
IF (RANK(K).EQ.1.0) STBMX=STBR(K)	PLA	1171
1400 CONTINUE	PLA	1172
1410 CONTINUE	PLA	1173
CVAG=0.0	PLA	1174
DO 1420 J=1,22	PLA	1175
IF (RSS(J).LT.13.0) GO TO 1420	PLA	1176
CVMX(J)=ACRES(J)*4047./3.07E08	PLA	1177
CVAG=CVAG+CVMX(J)	PLA	1178
CVMX(J)=CVMX(J)*CCVV(J)/CVTT	PLA	1179
1420 CONTINUE	PLA	1180
SFCT=0.0	PLA	1181
SFFB=0.0	PLA	1182
SFFC=0.0	PLA	1183
AAKK=0.0	PLA	1184
DO 1450 J=1,22	PLA	1185
IF (RANK(J).EQ.0.0) GO TO 1450	PLA	1186
AAKK=AAKK+1.0	PLA	1187
DO 1430 K=1,22	PLA	1188
IF (RANK(K).EQ.0.0) GO TO 1430	PLA	1189
IF (RANK(K).EQ.AAKK) GO TO 1440	PLA	1190
1430 CONTINUE	PLA	1191
GO TO 1450	PLA	1192
1440 SFAC(K)=(1.-SFCT)*CCVV(K)	PLA	1193
SFCT=SFCT+SFAC(K)	PLA	1194
IF (SFCT.GT.1.0) SFCT=1.0	PLA	1195
SFAC(K)=SFAC(K)/CCVV(K)	PLA	1196
SFAC(K)=SFAC(K)*STBR(K)/STBMX	PLA	1197
IF (SFAC(K).LE.0.01) SFAC(K)=0.01	PLA	1198
SFFB=SFFB+SFAC(K)	PLA	1199
1450 CONTINUE	PLA	1200
DO 1460 K=1,22	PLA	1201
IF (RANK(K).EQ.0.0) GO TO 1460	PLA	1202
SFAC(K)=SFAC(K)/SFFB	PLA	1203
SFAC(K)=SFAC(K)*(1.0-CVAG)	PLA	1204
SFFC=SFFC+SFAC(K)	PLA	1205
1460 CONTINUE	PLA	1206
DO 1480 K=1,22	PLA	1207
IF (RANK(K).EQ.0.0) GO TO 1480	PLA	1208
DO 1470 L=1,22	PLA	1209
IF (RSS(L).EQ.0.0) GO TO 1470	PLA	1210
IF (K.EQ.L) GO TO 1470	PLA	1211
IF (RSS(L).EQ.RSS(K)) SFAC(L)=SFAC(K)	PLA	1212
1470 CONTINUE	PLA	1213
1480 CONTINUE	PLA	1214
1490 CONTINUE	PLA	1215
C XXX	PLA	1216
DO 1500 K=1,22	PLA	1217

IF (RANK(K).EQ.0.0) GO TO 1500	PLA	1218
STBR(K)=CVMX(K)	PLA	1219
CCVV(K)=ACRES(K)	PLA	1220
CVMX(K)=SFAC(K)/SFFC	PLA	1221
1500 CONTINUE	PLA	1222
II=II+1	PLA	1223
PRINT 2050, AII	PLA	1224
PRINT 2080	PLA	1225
DO 1510 LPN=1,22	PLA	1226
IF (RGC(LPN).EQ.0.0) GO TO 1510	PLA	1227
PRINT 2030, B1(LPN),R1(LPN),D1(LPN),H1(LPN),RD1(LPN),RH1(LPN),CCVV	PLA	1228
1 (LPN),P1,TAV,MURAT(LPN),TPGNH(LPN),A1(LPN),LPN	PLA	1229
1510 CONTINUE	PLA	1230
PRINT 2040	PLA	1231
DO 1520 LPN=1,22	PLA	1232
IF (RGC(LPN).EQ.0.0) GO TO 1520	PLA	1233
PRINT 2030, A2(LPN),Z2(LPN),Z3(LPN),Z4(LPN),Z4R(LPN),Z5(LPN),Z5R	PLA	1234
1 (LPN),Z6(LPN),Z7(LPN),Z8(LPN),Z9(LPN),Z9R(LPN),LPN	PLA	1235
1520 CONTINUE	PLA	1236
PRINT 2070	PLA	1237
DO 1530 LPN=1,22	PLA	1238
IF (RGC(LPN).EQ.0.0) GO TO 1530	PLA	1239
Z7P=0.0	PLA	1240
Z7PR=0.0	PLA	1241
IF (D1(LPN).GT.0.0) Z7P=Z4(LPN)/D1(LPN)	PLA	1242
IF (RD1(LPN).GT.0.0) Z7PR=Z4R(LPN)/RD1(LPN)	PLA	1243
A22=A2(LPN)/BP	PLA	1244
A23=A22/ZP	PLA	1245
Z77=(Z7(LPN)+A2(LPN)/B1(LPN))/ZP	PLA	1246
PRINT 2030, Z77,Z7P,Z7PR,X8(LPN),A22,A23,Z1(LPN,1),Z1(LPN,2),CFAC	PLA	1247
1 (LPN),SFAC(LPN),LPN	PLA	1248
1530 CONTINUE	PLA	1249
DO 1540 LPN=1,22	PLA	1250
IF (RGC(LPN).EQ.0.0) GO TO 1540	PLA	1251
AAA(LPN)=0.0	PLA	1252
IF (RGC(LPN).NE.2.0) GO TO 1540	PLA	1253
CALL FORMAN (II,LPN,Z9(LPN),AAA(LPN))	PLA	1254
PRINT 1660, RINGT(LPN)	PLA	1255
1540 CONTINUE	PLA	1256
1550 CONTINUE	PLA	1257
GO TO 10	PLA	1258
C	PLA	1259
1560 FORMAT (8E10.3)	PLA	1260
1570 FORMAT (8F10.0)	PLA	1261
1580 FORMAT (1HA,50X,*TRU-BIOLOGICAL TRANSPORT MODEL*)	PLA	1262
1590 FORMAT (1H-,51X,*OPTIONS SPECIFIED AS INPUT*)	PLA	1263
1600 FORMAT (1H0,10X,*YEAR FOR DAILY OUTPUT FOR PLANT SIMULATION IS*,2X	PLA	1264
1 ,17)	PLA	1265
1610 FORMAT (1H0,10X,*NICHE COMPETITION MODULE WILL*,1X,A3,1X,*BE USED*	PLA	1266
1)	PLA	1267
1620 FORMAT (1H0,10X,*SUCCESSION MODULE WILL*,1X,A3,1X,*BE USED*)	PLA	1268
1630 FORMAT (1H0,10X,*CHRONIC EVENT OPTION WILL*,1X,A3,1X,*BE USED*)	PLA	1269
1640 FORMAT (1H0,10X,*IRRIGATION WILL*,1X,A3,1X,*BE USED*)	PLA	1270
1650 FORMAT (1H0,10X,*FORMAN SUBROUTINE WILL*,1X,A3,1X,*BE CALLED*)	PLA	1271
1660 FORMAT (10X,*RINGT INCREMENT,INCHES*,E11.4)	PLA	1272
1670 FORMAT (1H0,10X,*FORCUT SUBROUTINE WILL*,1X,A3,1X,*BE CALLED*)	PLA	1273
1680 FORMAT (1H0,10X,*RMINANT SUBROUTINE WILL*,1X,A3,1X,*BE CALLED*///)	PLA	1274
1690 FORMAT (1H-,47X,*TEMPERATURE CHARACTERISTICS FOR SITE*)	PLA	1275
1700 FORMAT (1H0,2X,*MAX. TEMP. VARIATION,DEG. F *,*MIN. SOLAR RADIATI	PLA	1276
ON LY/DAY *,*MAX. SOLAR RADIATION LY/DAY *,*RELATIVE ELEVATION,	PLA	1277
2FEET ABOVE SEA LEVEL*)	PLA	1278
1710 FORMAT (1H0,T19,E10.3,T48,E10.3,T78,E10.3,T119,E10.3)	PLA	1279
1720 FORMAT (1H0,2X,*MIN. MONTHLY TEMPERATURE,DEG. F *,*MAX. MONTHLY	PLA	1280
1 TEMPERATURE,DEG. F *,*LATITUDE RELATIVE TO SITE*)	PLA	1281

1730 FORMAT (1H0,T23,E10.3,T56,E10.3,T89,E10.3////)	PLA	1282
1740 FORMAT (1H-,46X,*PRECIPITATION CHARACTERISTICS FOR SITE*)	PLA	1283
1750 FORMAT (1H0,2X,*ANNUAL PRECIPITATION,INCHES *,*VARIATION COEFFIC	PLA	1284
11ENT FOR PRECIPITATION/EVENT *,*FROST-FREE PERIOD,DAYS *,*END	PLA	1285
2FROST-FREE PERIOD*)	PLA	1286
1760 FORMAT (1H0,T19,E10.3,T67,E10.3,T92,E10.3,T116,E10.3)	PLA	1287
1770 FORMAT (1H0,1X,*MONTHLY PRECIPITATIONS,FRACTION*)	PLA	1288
1780 FORMAT (2X,*JANUARY *,*FEBRUARY *,*MARCH *,*APRIL *	PLA	1289
1 *,*MAY *,*JUNE *,*JULY *,*AUGUST *,*SEPTEMB	PLA	1290
2ER *,*OCTOBER *,*NOVEMBER *,*DECEMBER*)	PLA	1291
1790 FORMAT (1H0,T3,E9.3,T14,E9.3,T25,E9.3,T36,E9.3,T47,E9.3,T58,E9.3	PLA	1292
1 ,T69,E9.3,T80,E9.3,T91,E9.3,T102,E9.3,T113,E9.3,T124,E9.3)	PLA	1293
1800 FORMAT (1H0,1X,*TOTAL RAINFALL EVENTS/MONTH*)	PLA	1294
1810 FORMAT (1H0,17X,E10.3)	PLA	1295
1820 FORMAT (1H-,47X,*SOIL CHARACTERISTICS OF SITE*)	PLA	1296
1830 FORMAT (1H0,2X,*FIELD CAPACITY,MM,H2O/250MM *,*HOLDING CAPACITY,M	PLA	1297
1M,H2O/250MM *,*WILTING POINT,MM,H2O/250MM *,*ACTIVITY OF SOIL	PLA	1298
2*,*SOIL DEPTH,MM*)	PLA	1299
1840 FORMAT (1H0,T18,E10.3,T50,E10.3,T78,E10.3,T97,E10.3,T114,E10.3////)	PLA	1300
1850 FORMAT (3X,*SOIL ACTIVITY, ACT/GRAM DRY WEIGHT IN GIVEN SOIL HORIZ	PLA	1301
1ON (Z1)*,3X,*PLANT NO. = *,3X,14)	PLA	1302
1860 FORMAT (3X,*ROOT FRACTION IN GIVEN SOIL HORIZON (ZF)*)	PLA	1303
1870 FORMAT (3X,*UPTAKE COEFFICIENT FOR A RADIONUCLIDE IN A GIVEN SOIL	PLA	1304
1HORIZON (ZU)*)	PLA	1305
1880 FORMAT (3X,12E10.3)	PLA	1306
1890 FORMAT (1H-,44X,*CHRONIC AND CONTAMINATING EVENTS*)	PLA	1307
1900 FORMAT (1H0,*INITIAL ACT. IN ATMOSPHERE/M2*,2X,*TOTAL " OF YEARS O	PLA	1308
1FEVENT*,2X,*DURATION OF EVENT,DAYS*,2X,*YR. OF INITIAL CONTAM. EVE	PLA	1309
2NT*,2X,*YR. OF CONTAM. ENDED*)	PLA	1310
1910 FORMAT (1H0,T19,E10.3,T46,E10.3,T69,E10.3,T99,E10.3,T119,E10.3)	PLA	1311
1920 FORMAT (1H0,*DAY OF INITIAL CONTAM. EVENT*,3X,*DAY OF FINAL CONTAM	PLA	1312
1INATION*)	PLA	1313
1930 FORMAT (1H0,T18,E10.3,T47,E10.3)	PLA	1314
1940 FORMAT (1H-,47X,*IRRIGATION CHARACTERISTICS FOR SITE*)	PLA	1315
1950 FORMAT (1H0,2X,*PLANT NO. = *,13,6X,*ACREAGE OF LAND = *,E10.3)	PLA	1316
1960 FORMAT (1H0,2X,*DAYS OF YEAR WATER APPLIED*)	PLA	1317
1970 FORMAT (3X,16E8.2)	PLA	1318
1980 FORMAT (1H0,2X,*WATER APPLIED ACRES/INCHES FOR DAYS OF YEAR*)	PLA	1319
1990 FORMAT (1H0,2X,*HARVESTING DATES, DAY OF YEAR*)	PLA	1320
2000 FORMAT (3X,6E11.4)	PLA	1321
2010 FORMAT (1H-,*DAILY OUTPUT FOR YEAR *,E9.3)	PLA	1322
2020 FORMAT (1H0,*B1 G/M2*,T12,*R1 G/M2*,T23,*D1 G/M2*,T34,*H1 G/M2*	PLA	1323
1 ,T45,*RD1 G/M2*,T56,*RH1 G/M2*,T67,*T,DEG.C*,T78,*P*,T89,*A1 ACT/	PLA	1324
2M3*,T100,*ZP ACT/G*,T111,*T5 ML/M2*,T122,*DAY NO.*,T132,*LPN*)	PLA	1325
2030 FORMAT (1X,E9.3,T12,E9.3,T23,E9.3,T34,E9.3,T45,E9.3,T56,E9.3,T67	PLA	1326
1 ,E9.3,T78,E9.3,T89,E9.3,T100,E9.3,T111,E9.3,T122,E9.3,T132,13)	PLA	1327
2040 FORMAT (1H0,*A2 ACT/M2*,T12,*Z2 ACT/M2*,T23,*Z3 ACT/M2*,T34,*Z4 AC	PLA	1328
1T/M2*,T45,*Z4R ACT/M2*,T56,*Z5 ACT/M2*,T67,*Z5R ACT/M2*,T78,*Z6 AC	PLA	1329
2T/G*,T89,*Z7 ACT/G*,T100,*Z8*,T111,*Z9 ACT/M2*,T122,*Z9R ACT/M2*	PLA	1330
3 ,T132,*LPN*)	PLA	1331
2050 FORMAT (1H-,*YEARLY OUTPUT FOR YEAR *,E9.3)	PLA	1332
2060 FORMAT (1H0,*B1 G/M2*,T12,*R1 G/M2*,T23,*D1 G/M2*,T34,*H1 G/M2*	PLA	1333
1 ,T45,*RD1 G/M2*,T56,*RH1 G/M2*,T67,*CCVV*,T78,*P1 *,T89,*TAV*	PLA	1334
2 ,T100,*MURAT*,T111,*TPGNW*,T122,*A1 ACT/M2*,T132,*LPN*)	PLA	1335
2070 FORMAT (1H0,*Z77*,T12,*Z7P ACT/G*,T23,*Z7PR ACT/G*,T34,*XB*,T45,*A	PLA	1336
122 ACT/G*,T56,*A23*,T67,*Z1 (LPN,1)*,T78,*Z1 (LPN,2)*,T89,*CFAC*	PLA	1337
2 ,T100,*SFAC*,T111,*LPN*)	PLA	1338
END	PLA	1339
FUNCTION AIRAC (SACH,YR,DAY)	PLA	1340
AIRAC=SACH	PLA	1341
RETURN	PLA	1342
END	PLA	1343
SUBROUTINE FORMAN (11,JK,Z99,AA)	FMG	2
COMMON H1(22), CCVV(22), A1(22), A2(22), B1(22), R1(22), D1(22),	FMG	3

1	B5(22), Z3(22), Z4(22), Z5(22), VTHBR(22,60), RD1(22), V8(22),	FMG	4
2	TPGNH(22), MND(22), Z2(22), Z4R(22), RSCF(22), SFAC(22), C8(22),	FMG	5
3	Z1(22,32), CFAC(22)	FMG	6
	COMMON YPRZ(4,32), PUTZD(4,22), ROC(22), ICA(22), ACRES(22), CUTA	FMG	7
1	(22,8)	FMG	8
	COMMON DTER(22,60), AGTB(22,60), AATB(22,60), SATB(22,60), C6(22)	FMG	9
	COMMON GTHBR(22,60), DATCT(22,32), TBRM(22), SCTP(22), RINGT(22)	FMG	10
	COMMON Z(60), C7, GA(60)	FMG	11
	DIMENSION X(60), G(60), COV(60), BAR(60), HGT(60), XJ1(22), C9(22)	FMG	12
	DIMENSION COVSQ(60), HOTSQ(60), BARSQ(60), ZZ3(22)	FMG	13
	DIMENSION MIND(22), TNHRT(22), WRSTR(22,20), BBP(22), VA(60)	FMG	14
	DATA ANOT, BLANK, DLY, YRLY /3=NOT,3H ,6=DAILY,6=YEARLY/	FMG	15
	IF (TBRM(JK).NE.0.1) GO TO 10	FMG	16
	READ 250, TNHRT(JK),TBRM(JK),XJ1(JK),V8(JK),C9(JK),C6(JK)	FMG	17
	V8(JK)=C9(JK)/V8(JK)	FMG	18
	INHRT=TNHRT(JK)	FMG	19
	IBRM=TBRM(JK)	FMG	20
	BBP(JK)=0.0	FMG	21
	MIND(JK)=0.0	FMG	22
	M=0	FMG	23
	RINGT(JK)=0.0	FMG	24
	READ 250, (WRSTR(JK,L),L=1,INHRT)	FMG	25
	IF (TBRM(JK).GT.0.0) READ 250, (DATCT(JK,L),L=1,IBRM)	FMG	26
	IF (TBRM(JK).GT.0.0) CALL FORCUT (11,M,Z99,AA,JK)	FMG	27
	RETURN	FMG	28
10	CONTINUE	FMG	29
	A11=11	FMG	30
	IBRM=TBRM(JK)	FMG	31
	IF (IBRM.EQ.0) IBRM=1	FMG	32
	DO 20 K=1,IBRM	FMG	33
	IF (TBRM(JK).EQ.0.0) GO TO 20	FMG	34
	IF (DATCT(JK,K).NE.A11+1.0) GO TO 20	FMG	35
	BBP(JK)=B1(JK)*.142*V8(JK)*(1.-CCVV(JK)/2.)/(SFAC(JK)*CFAC(JK))	FMG	36
	RETURN	FMG	37
20	CONTINUE	FMG	38
	TCR=RSCF(JK)	FMG	39
	IF (ROC(JK).EQ.3.0) TCR=365.	FMG	40
	T1=773.*(XJ1(JK)/2.)*(1.-CCVV(JK)/2.)	FMG	41
	V5=.142*V8(JK)*B1(JK)*(1.-CCVV(JK)/2.)/(SFAC(JK)*CFAC(JK))	FMG	42
	C8(JK)=1.0	FMG	43
	IF (V5.LT.T1) RETURN	FMG	44
	MIND(JK)=MIND(JK)+1.0	FMG	45
	G4=.142*B1(JK)*V8(JK)*(1.-CCVV(JK)/2.)/(SFAC(JK)*CFAC(JK))	FMG	46
	G4=G4-BBP(JK)	FMG	47
	BBP(JK)=B1(JK)*.142*V8(JK)*(1.-CCVV(JK)/2.)/(SFAC(JK)*CFAC(JK))	FMG	48
	V4=0.142*B1(JK)	FMG	49
	M=MIND(JK)	FMG	50
	IF (M.GT.1) GO TO 40	FMG	51
	DO 30 L=1,60	FMG	52
	VTHBR(JK,L)=0.0	FMG	53
	DTER(JK,L)=0.0	FMG	54
	Z(L)=0.0	FMG	55
	GTHBR(JK,L)=0.0	FMG	56
	AGTB(JK,L)=0.0	FMG	57
	AATB(JK,L)=0.0	FMG	58
	SATB(JK,L)=0.0	FMG	59
	GA(L)=0.0	FMG	60
	VA(L)=0.0	FMG	61
	ZZ3(JK)=0.0	FMG	62
30	CONTINUE	FMG	63
40	CONTINUE	FMG	64
	V2=0.3*(0.035*V8(JK))*(2.0*2.54)**2	FMG	65
	GOTHB=VTHBR(JK,1)	FMG	66
	GTHBR(JK,1)=T1*EXP(-(1./RSCF(JK))*(V5-T1))	FMG	67

IF (GTMR(JK,1).GT.V5) GTMR(JK,1)=V5	FMG	68
IF (GTMR(JK,1).EQ.V5) RETURN	FMG	69
IF (GTMR(JK,1).LE.V2) GTMR(JK,1)=0.0	FMG	70
VTMR(JK,1)=GTMR(JK,1)*V4/V5	FMG	71
DGTMB=VTMR(JK,1)-GGTMB	FMG	72
DTBR(JK,1)=VTMR(JK,1)/V2	FMG	73
AGSUM=0.0	FMG	74
ACTSM=0.0	FMG	75
TREES=0.0	FMG	76
HTAV=0.0	FMG	77
COVAV=0.0	FMG	78
BAAV=0.0	FMG	79
HTSQ=0.0	FMG	80
CVSQ=0.0	FMG	81
BSQ=0.0	FMG	82
CB(JK)=1.0	FMG	83
C4=0.0	FMG	84
CVTR=0.0	FMG	85
DO 80 N=1,60	FMG	86
AN=N	FMG	87
COV(N)=0.0	FMG	88
BAR(N)=0.0	FMG	89
HGT(N)=0.0	FMG	90
X(N)=0.0	FMG	91
IF (GTMR(JK,N).LE.0.0) GO TO 80	FMG	92
AN=AN*XJ1(JK)-XJ1(JK)/2.	FMG	93
X(N)=(AN*CB(JK)+VB(JK))*2	FMG	94
X(N)=X(N)*(AN*2)*DTBR(JK,N)	FMG	95
IF (N.EQ.1) GO TO 70	FMG	96
COV(N)=.0929*3.1416*((AN*CB(JK)+VB(JK))/2.)*2	FMG	97
HGT(N)=(122./(VB(JK)))*(AN/24.)*0.904	FMG	98
BAR(N)=AN	FMG	99
COV(N)=DTBR(JK,N)*COV(N)	FMG	100
HGT(N)=DTBR(JK,N)*HGT(N)	FMG	101
BAR(N)=DTBR(JK,N)*ALOG(BAR(N))	FMG	102
TREES=TREES+DTBR(JK,N)	FMG	103
COVSQ(N)=DTBR(JK,N)*(COV(N)/DTBR(JK,N))*2	FMG	104
HGTSQ(N)=DTBR(JK,N)*(HGT(N)/DTBR(JK,N))*2	FMG	105
BARSQ(N)=DTBR(JK,N)*(BAR(N)/DTBR(JK,N))*2	FMG	106
IF (AATB(JK,N).LE.0.0) GO TO 50	FMG	107
AGSUM=AGSUM+DTBR(JK,N)*ALOG(AATB(JK,N))	FMG	108
50 IF (SATB(JK,N).LE.0.0) GO TO 60	FMG	109
ACTSM=ACTSM+DTBR(JK,N)*ALOG(SATB(JK,N))	FMG	110
60 HTAV=HTAV+HGT(N)	FMG	111
COVAV=COVAV+COV(N)	FMG	112
BAAV=BAAV+BAR(N)	FMG	113
HTSQ=HTSQ+HGTSQ(N)	FMG	114
CVSQ=CVSQ+COVSQ(N)	FMG	115
BSQ=BSQ+BARSQ(N)	FMG	116
HGT(N)=HGT(N)/DTBR(JK,N)	FMG	117
COV(N)=COV(N)/DTBR(JK,N)	FMG	118
BAR(N)=AN	FMG	119
CVTR=CVTR+DTBR(JK,N)*3.1416*(BAR(N)/24.)*2	FMG	120
70 IF (X(N).LE.0.0) GO TO 80	FMG	121
CB(JK)=CB(JK)+X(N)	FMG	122
IF (N.GT.1) C4=C4+1/X(N)	FMG	123
80 CONTINUE	FMG	124
IF (TREES.LE.0.0) GO TO 50	FMG	125
DF=TREES-1.0	FMG	126
IF (DF.LT.1.0) DF=1.0	FMG	127
BSD=(BSQ-BAAV**2/TREES)/DF	FMG	128
HTSD=(HTSQ-HTAV**2/TREES)/DF	FMG	129
CVSD=(CVSQ-COVAV**2/TREES)/DF	FMG	130
BSD=EXP(BSD)	FMG	131

IF (BSD.GT.0.0) BSD=SQRT(BSD)	FMG	132
IF (HTSD.GT.0.0) HTSD=SQRT(HTSD)	FMG	133
IF (CVSD.GT.0.0) CVSD=SQRT(CVSD)	FMG	134
CVMN=COVAV/TREES	FMG	135
BMN=EXP(BAAV/TREES)	FMG	136
HTAV=HTAV/TREES	FMG	137
COVAV=CVMN*TREES/4047.	FMG	138
BATR=(122./(VB(JK)))*(BMN/24.)*0.904	FMG	139
AGAVE=EXP(AGSUM/TREES)	FMG	140
ACTAV=EXP(ACTSM/TREES)	FMG	141
IF (COVAV.GT.1.0) COVAV=1.0	FMG	142
CCVV(JK)=COVAV	FMG	143
90 V6=GTHBR(JK,1)	FMG	144
TOTSA=Z3(JK)	FMG	145
IF (TOTSA.LT.0.0) TOTSA=1.0	FMG	146
ACTS=Z3(JK)-Z23(JK)	FMG	147
DO 110 L=2,60	FMG	148
IF (X(L-1).LE.0.0.AND.X(L).LE.0.0) GO TO 100	FMG	149
AL=L	FMG	150
AL9=AL*XJ1(JK)-XJ1(JK)/2.	FMG	151
DD=XJ1(JK)/2.	FMG	152
Z(L)=0.035*(VB(JK))*((AL9-DD)*2.54)**2	FMG	153
Z(L)=(Z(L)+.035*(VB(JK))*((AL9+DD)*2.54)**2)/2.	FMG	154
G3=G4*X(L-1)/CB(JK)	FMG	155
G30=G4*X(L)/CB(JK)	FMG	156
GGTM=GTHBR(JK,L)	FMG	157
GTHBR(JK,L)=GTHBR(JK,L)+(X(L-1)-X(L))*G30/(X(L-1)+X(L))+G3	FMG	158
IF (G4.LE.0.0) GTHBR(JK,L)=GGTM+G4*(GGTM/V5)*((CB(JK)-X(L))/CB(JK)	FMG	159
I)	FMG	160
GTHBR(JK,L)=GTHBR(JK,L)-CCVV(JK)*GTHBR(JK,L)/(TCR*(CB(JK)-X(L))/CB	FMG	161
I (JK))	FMG	162
100 IF (GTHBR(JK,L).LT.Z(L)*77.3/V4) GTHBR(JK,L)=0.0	FMG	163
IF (GTHBR(JK,L).EQ.0.0) GO TO 110	FMG	164
V6=V6+GTHBR(JK,L)	FMG	165
IF (X(L).GT.1.0) GO TO 110	FMG	166
CB(JK)=CB(JK)-X(L)+1.0	FMG	167
C4=C4+1.0	FMG	168
IF (X(L).GT.0.0) C4=C4-1.0/X(L)	FMG	169
X(L)=1.0	FMG	170
110 CONTINUE	FMG	171
V4M6=V5-V6	FMG	172
C7=VTHBR(JK,1)	FMG	173
TREES=0.0	FMG	174
DO 140 L=2,60	FMG	175
IF (X(L).EQ.0.0) GO TO 140	FMG	176
IF (GTHBR(JK,L).LE.0.0) GTHBR(JK,L)=Z(L)*77.3/V4	FMG	177
AL9=L	FMG	178
AL9=(AL9*XJ1(JK)-XJ1(JK)/2.0)/2.0	FMG	179
IF (CB(JK).NE.X(1)) GO TO 120	FMG	180
GTHBR(JK,2)=V5-GTHBR(JK,1)	FMG	181
GO TO 130	FMG	182
120 GGTM=GTHBR(JK,L)	FMG	183
GTHBR(JK,L)=GTHBR(JK,L)+V4M6*X(L)/(CB(JK)-X(1))	FMG	184
IF (V4M6.LT.0.0) GTHBR(JK,L)=GGTM+V4M6*(1.0/X(L))/C4	FMG	185
130 IF (GTHBR(JK,L).LE.0.0) GTHBR(JK,L)=0.0	FMG	186
VVTM=VTHBR(JK,L)	FMG	187
VTHBR(JK,L)=GTHBR(JK,L)*V4/V5	FMG	188
DTBR(JK,L)=VTHBR(JK,L)/Z(L)	FMG	189
IF (VTHBR(JK,L).LE.0.0) VA(L)=0.0	FMG	190
IF (VTHBR(JK,L).LE.0.0) SATB(JK,L)=0.0	FMG	191
IF (VTHBR(JK,L).LE.0.0) GO TO 140	FMG	192
C7=C7+VTHBR(JK,L)	FMG	193
TREES=TREES+DTBR(JK,L)	FMG	194
VDTEM=VTHBR(JK,L)-VVTM	FMG	195

IF (VWTH.LE.0.0) VWTH=VTHER(JK,L)	FMG	196
IF (VWTH.GT.VTHER(JK,L)) VWTH=VTHER(JK,L)	FMG	197
RINGT(JK)=RINGT(JK)+AL9*(SORT(VTHER(JK,L)/VWTH)-1.0)*DTBR(JK,L)	FMG	198
VA(L)=VTHER(JK,L)*SATB(JK,L)/0.142	FMG	199
VA(L)=VA(L)+ABS(G4)*ACTS*X(L)/CB(JK)	FMG	200
SATB(JK,L)=VA(L)/(VTHER(JK,L)/.142)	FMG	201
VA(L)=VA(L)+(VDTBM/.142)*SATB(JK,L)	FMG	202
IF (VA(L).LT.0.0) VA(L)=0.0	FMG	203
IF (X(L).EQ.1.0) SATB(JK,L)=SATB(JK,L-1)	FMG	204
140 CONTINUE	FMG	205
IF (TREES.GT.0.0) RINGT(JK)=RINGT(JK)/TREES	FMG	206
VA(1)=VTHER(JK,1)*SATB(JK,1)/.142	FMG	207
SATB(JK,1)=0.0	FMG	208
IF (VTHER(JK,1).LE.0.0) VA(1)=0.0	FMG	209
IF (VTHER(JK,1).LE.0.0) GO TO 150	FMG	210
VA(1)=VA(1)+ABS(G4)*ACTS*X(1)/CB(JK)	FMG	211
SATB(JK,1)=VA(1)/(VTHER(JK,1)/.142)	FMG	212
VA(1)=VA(1)+(DGTBM/.142)*SATB(JK,1)	FMG	213
IF (VA(1).LT.0.0) VA(1)=0.0	FMG	214
SATB(JK,1)=VA(1)/(VTHER(JK,1)/.142)	FMG	215
150 TOTAC=SATB(JK,1)*VTHER(JK,1)/0.142	FMG	216
IF (TOTSA.EQ.1.0) TOTAC=1.0	FMG	217
IF (TOTAC.LE.0.0) TOTAC=1.0	FMG	218
DO 160 L=1,60	FMG	219
IF (AGTB(JK,L).GT.0.0) GO TO 160	FMG	220
IF (VTHER(JK,L+1).GT.0.0) AGTB(JK,L)=A11	FMG	221
160 IF (L.EQ.1) GO TO 180	FMG	222
IF (AGTB(JK,L-1).EQ.0.0) GO TO 170	FMG	223
IF (L.EQ.2) AATB(JK,L-1)=AGTB(JK,L-1)/2.0	FMG	224
IF (L.EQ.2) GA(L-1)=AGTB(JK,L-1)	FMG	225
IF (L.EQ.2) GO TO 170	FMG	226
AATB(JK,L-1)=(AGTB(JK,L)+AGTB(JK,L-1))/2.0	FMG	227
IF (AGTB(JK,L).EQ.0.0 AND L.GT.2) AATB(JK,L-1)=2.*AATB(JK,L-1)	FMG	228
GA(L-1)=AGTB(JK,L)-AGTB(JK,L-1)	FMG	229
IF (GA(L-1).LT.0.0) GA(L-1)=AGTB(JK,L-1)	FMG	230
170 CONTINUE	FMG	231
IF (VTHER(JK,L).LE.0.0) GO TO 180	FMG	232
TOTAC=TOTAC+SATB(JK,L)*VTHER(JK,L)/0.142	FMG	233
180 CONTINUE	FMG	234
IF (TOTAC.EQ.1.0) TOTSA=1.0	FMG	235
SATB(JK,1)=SATB(JK,1)*TOTSA/TOTAC	FMG	236
IF (SATB(JK,1).LT.0.0) SATB(JK,1)=0.0	FMG	237
DO 190 LK=1,INWRT	FMG	238
IF (WRSTRI(JK,LK).EQ.A11) GO TO 200	FMG	239
190 CONTINUE	FMG	240
WRT=0.0	FMG	241
GO TO 230	FMG	242
200 WRT=1.0	FMG	243
BAR(1)=BAR(1)/4047.	FMG	244
COV(1)=COV(1)/4047.	FMG	245
IF (RGC(JK).EQ.2.0) PRINT 270, YRLY,TNWRT(JK)	FMG	246
IF (RGC(JK).EQ.3.0) PRINT 270, DLY,TNWRT(JK)	FMG	247
IF (TBRM(JK).GT.0.0) PRINT 320	FMG	248
IF (TBRM(JK).GT.0.0) PRINT 260, (DATCT(JK,L),L=1,IBRM)	FMG	249
PRINT 280	FMG	250
KJ=JK	FMG	251
PRINT 310, HTAV,HTSD,CVMN,CVSD,BMN,BSD,COVAV,BATR,TREES,AGAVE	FMG	252
1 ,ACTAV	FMG	253
B2=1.0	FMG	254
PRINT 290	FMG	255
KJ=JK	FMG	256
PRINT 310, B2,VTHER(KJ,1),DTBR(KJ,1),T1,V4,SATB(KJ,1),CVTR	FMG	257
DO 210 L=2,60	FMG	258
AL=L	FMG	259

	AL9=AL*XJ1(JK)-XJ1(JK)/2.0	FMG	260
	SATB(JK,L)=SATB(JK,L)*TOTSA/TOTAC	FMG	261
	IF (SATB(JK,L).LT.0.0) SATB(JK,L)=0.0	FMG	262
210	CONTINUE	FMG	263
	PRINT 300	FMG	264
	KJ=JK	FMG	265
	DO 220 L=2,60	FMG	266
	IF (GTHBR(JK,L).EQ.0.0) GO TO 220	FMG	267
	AL9=L	FMG	268
	AL9=AL9*XJ1(KJ)	FMG	269
	AL9=AL9-XJ1(KJ)/2.0	FMG	270
	VOLTR=VTHBR(KJ,L)/DTBR(KJ,L)	FMG	271
	PRINT 310, AL9,VTHBR(KJ,L),GTHBR(KJ,L),DTBR(KJ,L),COV(L),BAR(L)	FMG	272
	1 ,VOLTR,GA(L),AATB(KJ,L),SATB(KJ,L)	FMG	273
220	CONTINUE	FMG	274
230	CONTINUE	FMG	275
	DO 240 L=1,60	FMG	276
	ZZ3(JK)=Z3(JK)	FMG	277
	IF (XART.EQ.0.0) SATB(JK,L)=SATB(JK,L)*TOTSA/TOTAC	FMG	278
240	CONTINUE	FMG	279
	IF (TERM(JK).EQ.0.0) RETURN	FMG	280
	CALL FORCUT (11,M,Z99,AA,JK)	FMG	281
	RETURN	FMG	282
C		FMG	283
250	FORMAT (BF10.0)	FMG	284
260	FORMAT (3X,11E11.4)	FMG	285
270	FORMAT (1H-,*FORMAN OUTPUT ON*,1X,A6,*BASIS*,3X,F4.0,1X,*PRINTOUTS	FMG	286
	1 REQUIRED*)	FMG	287
280	FORMAT (1H0,*HTAV*,T14,*HTSD*,T26,*CVMN*,T38,*CVSD*,T50,*BMN*,T62,	FMG	288
	1 *BSD*,T74,*COVAV*,T86,*BATR*,T98,*TREES*,T110,*AGAVE*,T122,*ACTAV	FMG	289
	2*)	FMG	290
290	FORMAT (1H0,*B2*,T14,*VTHBR(JK,1)*,T26,*DTBR(JK,1)*,T38,*T1*,T50,*	FMG	291
	1V4*,T62,*SATB(JK,1)*,T74,*CVTR*)	FMG	292
300	FORMAT (1H0,*AL9*,T14,*VTHBR(JK,L)*,T26,*GTHBR(JK,L)*,T38,*DTBR(JK	FMG	293
	1,L)*,T50,*COV(L)*,T62,*BAR(L)*,T74,*VOLTR*,T86,*GA(L)*,T98,*AATB(J	FMG	294
	2 K,L)*,T110,*SATB(JK,L)*)	FMG	295
310	FORMAT (1H0,E10.4,T14,E10.4,T26,E10.4,T38,E10.4,T50,E10.4,T62,E10.	FMG	296
	1 4,T74,E10.4,T86,E10.4,T98,E10.4,T110,E10.4,T122,E10.4)	FMG	297
320	FORMAT (1H0,*DAY NUMBERS OF SPECIFIC MANAGEMENT GENERATIONS*)	FMG	298
	END	FMG	299
	SUBROUTINE FORCUT (11,M,Z99,AA,JK)	FCT	2
	COMMON H1(22), CCVV(22), A1(22), A2(22), B1(22), R1(22), D1(22),	FCT	3
	1 B5(22), Z3(22), Z4(22), Z5(22), VTHBR(22,60), RDI(22), V8(22),	FCT	4
	2 TPGNW(22), WND(22), Z2(22), Z4R(22), RSCF(22), SFAC(22), C8(22),	FCT	5
	3 Z1(22,32), CFAC(22)	FCT	6
	COMMON YRGRZ(4,32), PUTZD(4,22), RGC(22), ICA(22), ACRES(22), CUTA	FCT	7
	1 (22,8)	FCT	8
	COMMON DTBR(22,60), AGTB(22,60), AATB(22,60), SATB(22,60), C6(22)	FCT	9
	COMMON GTHBR(22,60), DATCT(22,32), TERM(22), SCTP(22), RINGT(22)	FCT	10
	COMMON Z(60), C7, GA(60)	FCT	11
	DIMENSION TCUT(22,32), ACUT(22,2), BCUT(22,2), CCUT(22,2), VCUT(60	FCT	12
	1)	FCT	13
	DIMENSION RACUT(22), RBCUT(22), RCCUT(22)	FCT	14
	IF (M.GT.0) GO TO 10	FCT	15
	IBRM=TERM(JK)	FCT	16
	READ 190, (TCUT(JK,1),I=1,IBRM)	FCT	17
C	1=CHOICE CUT,SAINTIMBER(12-40),PULPWOOD(6-10),PRECOMM(0-4),CLEAR CU	FCT	18
C	2=REVERSE-J CUT,AND ALL SIZES ABOVE 26 INCHES DIA. REMOVED	FCT	19
C	3=FIRE OCCURANCE,ALL CLASSES AFFECTED	FCT	20
	READ 190, ACUT(JK,1),ACUT(JK,2),BCUT(JK,1),BCUT(JK,2),CCUT(JK,1)	FCT	21
	1 ,CCUT(JK,2)	FCT	22
	READ 190, RACUT(JK),RBCUT(JK),RCCUT(JK)	FCT	23
10	CONTINUE	FCT	24
	IBRM=TERM(JK)	FCT	25

A11=11	FCT	26
DO 20 K=1,1BRM	FCT	27
KK=K	FCT	28
IF (DATCT(JK,K).EQ.A11) GO TO 30	FCT	29
20 CONTINUE	FCT	30
RETURN	FCT	31
30 ITC=TCUT(JK,KK)	FCT	32
VTOT=0.0	FCT	33
DO 40 K=1,60	FCT	34
40 VCUT(K)=0.0	FCT	35
IF (ITC.EQ.2)GOTO120	FCT	36
50 IA1=ACUT(JK,1)	FCT	37
IA2=ACUT(JK,2)	FCT	38
IB1=BCUT(JK,1)	FCT	39
IB2=BCUT(JK,2)	FCT	40
IC1=CCUT(JK,1)	FCT	41
IC2=CCUT(JK,2)	FCT	42
IF (IA1.EQ.0) GO TO 70	FCT	43
DO 60 K=IA1,IA2	FCT	44
IF (VTHER(JK,K).LE.0.0) GO TO 60	FCT	45
VCUT(K)=VTHER(JK,K)*(1.-RACUT(JK))	FCT	46
DTBR(JK,K)=DTBR(JK,K)*(VTHER(JK,K)-VCUT(K))/VTHER(JK,K)	FCT	47
VTOT=VTOT+VCUT(K)	FCT	48
60 CONTINUE	FCT	49
70 IF (IB1.EQ.0) GO TO 90	FCT	50
DO 80 K=IB1,IB2	FCT	51
IF (VTHER(JK,K).LE.0.0) GO TO 80	FCT	52
VCUT(K)=VTHER(JK,K)*(1.-RBCUT(JK))	FCT	53
DTBR(JK,K)=DTBR(JK,K)*(VTHER(JK,K)-VCUT(K))/VTHER(JK,K)	FCT	54
VTOT=VTOT+VCUT(K)	FCT	55
80 CONTINUE	FCT	56
90 IF (IC1.EQ.0) GO TO 110	FCT	57
DO 100 K=IC1,IC2	FCT	58
IF (VTHER(JK,K).LE.0.0) GO TO 100	FCT	59
VCUT(K)=VTHER(JK,K)*(1.-RCCUT(JK))	FCT	60
DTBR(JK,K)=DTBR(JK,K)*(VTHER(JK,K)-VCUT(K))/VTHER(JK,K)	FCT	61
VTOT=VTOT+VCUT(K)	FCT	62
100 CONTINUE	FCT	63
110 IF (ITC.EQ.3) GO TO 150	FCT	64
GO TO 170	FCT	65
120 DO 140 K=1,60	FCT	66
AK=2.*K	FCT	67
IF (VTHER(JK,K).LE.0.0) GO TO 140	FCT	68
IF (AK.GE.26.) GO TO 130	FCT	69
RVJ=126.0*EXP(-.197*AK)	FCT	70
RVJ=RVJ*Z(K)	FCT	71
IF (VTHER(JK,K).LE.RVJ) GO TO 140	FCT	72
VCUT(K)=VTHER(JK,K)-RVJ	FCT	73
DTBR(JK,K)=DTBR(JK,K)*(VTHER(JK,K)-VCUT(K))/VTHER(JK,K)	FCT	74
VTOT=VTOT+VCUT(K)	FCT	75
GO TO 140	FCT	76
130 VCUT(K)=VTHER(JK,K)	FCT	77
DTBR(JK,K)=DTBR(JK,K)*(VTHER(JK,K)-VCUT(K))/VTHER(JK,K)	FCT	78
VTOT=VTOT+VCUT(K)	FCT	79
140 CONTINUE	FCT	80
GO TO 170	FCT	81
150 DO 160 K=2,60	FCT	82
IF (VTHER(JK,K).LE.0.0.OR.VCUT(K).LE.0.0) GO TO 160	FCT	83
VTHER(JK,K)=VTHER(JK,K)-VCUT(K)	FCT	84
GTHBR(JK,K)=VTHER(JK,K)*VB(JK)*(1.-CCVV(JK)/2.)/(SFAC(JK)*CFAC(JK)	FCT	85
1)	FCT	86
Z99=Z99+.7*VCUT(K)*SATB(JK,K)/.141	FCT	87
AA=AA+.1*VCUT(K)*SATB(JK,K)/(.141*30.)	FCT	88
Z4(JK)=Z4(JK)+0.2*SATB(JK,K)*VCUT(K)/.141	FCT	89

Z3(JK)=Z3(JK)-SATB(JK,K)*VCUT(K)/.141	FCT	90
160 CONTINUE	FCT	91
RD1(JK)=RD1(JK)+R1(JK)*VTOT/C7	FCT	92
Z4R(JK)=Z4R(JK)+Z2(JK)*VTOT/C7	FCT	93
Z2(JK)=Z2(JK)-Z2(JK)*VTOT/C7	FCT	94
WHD(JK)=WHD(JK)*(C7-VTOT)/C7	FCT	95
TPGNH(JK)=TPGNH(JK)*(C7-VTOT)/C7	FCT	96
R1(JK)=R1(JK)-R1(JK)*VTOT/C7	FCT	97
B1(JK)=B1(JK)*(C7-VTOT)/C7	FCT	98
PRINT 210	FCT	99
PRINT 200, 18RM	FCT	100
PRINT 220, (TCUT(JK,I),I=1,18RM)	FCT	101
PRINT 230	FCT	102
KJ=JK	FCT	103
PRINT 240, C7,VTOT,B1(KJ),R1(KJ),D1(KJ),Z3(KJ),Z2(KJ),Z4(KJ),A11	FCT	104
RETURN	FCT	105
170 D1(JK)=D1(JK)+B1(JK)*.25*VTOT/C7	FCT	106
RD1(JK)=RD1(JK)+R1(JK)*VTOT/C7	FCT	107
DO 180 K=2,60	FCT	108
IF (VTHER(JK,K).LE.0.0.OP.VCUT(K).LE.0.0) GO TO 180	FCT	109
VTHER(JK,K)=VTHER(JK,K)-VCUT(K)	FCT	110
GTHBR(JK,K)=VTHER(JK,K)*VB(JK)*(1.-CCVV(JK)/2.)/(SFAC(JK)*CFAC(JK)	FCT	111
1)	FCT	112
Z4(JK)=Z4(JK)+.25*SATB(JK,K)*VCUT(K)/.141	FCT	113
Z3(JK)=Z3(JK)-SATB(JK,K)*VCUT(K)/.141	FCT	114
180 CONTINUE	FCT	115
Z4R(JK)=Z4R(JK)+Z2(JK)*VTOT/C7	FCT	116
Z2(JK)=Z2(JK)-Z2(JK)*VTOT/C7	FCT	117
WHD(JK)=WHD(JK)*(C7-VTOT)/C7	FCT	118
TPGNH(JK)=TPGNH(JK)*(C7-VTOT)/C7	FCT	119
R1(JK)=R1(JK)-R1(JK)*VTOT/C7	FCT	120
B1(JK)=B1(JK)*(C7-VTOT)/C7	FCT	121
PRINT 230	FCT	122
KJ=JK	FCT	123
PRINT 240, C7,VTOT,B1(KJ),R1(KJ),D1(KJ),Z3(KJ),Z2(KJ),Z4(KJ),A11	FCT	124
RETURN	FCT	125
C	FCT	126
190 FORMAT (8F10.0)	FCT	127
200 FORMAT (1H-,*FORCUT OUTPUT TERM= *,17)	FCT	128
210 FORMAT (1H0,2X,*TYPE OF CUTTING EVENT, 1 = CHOICE CUT, 2 = REVERSE	FCT	129
1-J CUT, 3 = FIRE OCCURANCE*)	FCT	130
220 FORMAT (3X,11E11.4)	FCT	131
230 FORMAT (1H0,*C7*,T14,*VTOT*,T26,*B1(JK)*,T38,*R1(JK)*,T50,*D1(JK)*	FCT	132
1 ,T62,*Z3(JK)*,T74,*Z4(JK)*,T86,*A11*,)	FCT	133
240 FORMAT (1H0,E10.4,T14,E10.4,T26,E10.4,T38,E10.4,T50,E10.4,T62,E10.	FCT	134
1 4,T74,E10.4,T86,E10.4,T98,E10.4)	FCT	135
END	FCT	136
SUBROUTINE RHINANT (11,111,A1TT,XHERB)	ANL	2
COMMON H1(22), CCVV(22), A1(22), A2(22), B1(22), R1(22), D1(22),	ANL	3
1 B5(22), Z3(22), Z4(22), Z5(22), VTHER(22,60), RD1(22), VB(22),	ANL	4
2 TPGNH(22), WHD(22), Z2(22), Z4R(22), RSCF(22), SFAC(22), CB(22),	ANL	5
3 Z1(22,32), CFAC(22)	ANL	6
COMMON YGRGZ(4,32), PUTZD(4,22), ROC(22), ICA(22), ACRES(22), CUTA	ANL	7
1 (22,8)	ANL	8
COMMON GTHBR(22,60), DATCT(22,32), TBRM(22), SCTP(22), RINGT(22)	ANL	9
DIMENSION W(20,4), R(8,4), S(8,4), U(8,4), P(8,4), M(8,4), X(8,4),	ANL	10
1 Y(8,4)	ANL	11
DIMENSION ONRNG(4,32), FSUFF(4), RR(4), P4(22), PP6(22), CNIT(22),	ANL	12
1 UP(3), Z(8,4), Q(8,4), V(8,4), N5(4), P5(4), AA2(4), PNIT(22),	ANL	13
2 SNIT(22)	ANL	14
DIMENSION WATER(22), A(22), QSUM(3), GTDR(3), TNIT(3), SACT(3),	ANL	15
1 OFRAC(3)	ANL	16
DIMENSION SAIR(3), ANMAL(4,32), HUMUS(4), G(22), D(22)	ANL	17
DIMENSION HRVST(4), HRVSP(4), SPAC(4), SPAS(4), SPAP(4), SPAA(4)	ANL	18

	DIMENSION SPAR(4), SAAP(4), TOTSF(4), SPUT(4)	ANL	19
	REAL N, N3, N4, N2, M, M2, L1, L2, L4, L5, M1, M4, M5, M7, M6, N5	ANL	20
	DATA 112 /0/	ANL	21
	A11=11	ANL	22
	A111=111	ANL	23
	112=112+1	ANL	24
	IF (112.GT.1) GO TO 130	ANL	25
	READ 400, (RR(L),L=1,4)	ANL	26
	DO 10 J=1,4	ANL	27
	PS(J)=0.0	ANL	28
	N5(J)=0.0	ANL	29
	AA2(J)=0.0	ANL	30
	FSUFF(J)=0.0	ANL	31
	SPUT(J)=0.0	ANL	32
	IF (RR(J).EQ.0.0) GO TO 10	ANL	33
C	PS=FRAC BEEF PROD CONS IN REG,N5=NO.ANIMALS,AA2=FRAC AREA GRAZED	ANL	34
	READ 400, PS(J),N5(J),AA2(J),FSUFF(J)	ANL	35
	READ 400, (YGRZ(J,L),L=1,32)	ANL	36
	READ 400, (ONRNG(J,L),L=1,32)	ANL	37
	READ 400, (ANMAL(J,L),L=1,32)	ANL	38
	READ 400, (PUTZD(J,L),L=1,22)	ANL	39
10	CONTINUE	ANL	40
	N2=1.0	ANL	41
	N4=1.0	ANL	42
	M1=0.52	ANL	43
	F1=0.04	ANL	44
	E6=0.25	ANL	45
	N3=0.6	ANL	46
	W(17,1)=550.0	ANL	47
	M7=3.73E08	ANL	48
	W(1,1)=23.	ANL	49
	W(2,1)=290.4	ANL	50
	W(3,1)=410.3	ANL	51
	W(4,1)=494.4	ANL	52
	W(5,1)=550.0	ANL	53
	W(6,1)=550.	ANL	54
	W(7,1)=550.	ANL	55
	W(8,1)=550.	ANL	56
	Z(1,1)=0.4	ANL	57
	Z(2,1)=.06	ANL	58
	Z(3,1)=.12	ANL	59
	Z(4,1)=.18	ANL	60
	Z(5,1)=.12	ANL	61
	Z(6,1)=.06	ANL	62
	Z(7,1)=.036	ANL	63
	Z(8,1)=.024	ANL	64
	W(11,1)=0.0	ANL	65
	Z(1,3)=0.25	ANL	66
	Z(2,3)=0.23	ANL	67
	Z(3,3)=0.16	ANL	68
	Z(4,3)=0.12	ANL	69
	Z(5,3)=0.12	ANL	70
	Z(6,3)=0.05	ANL	71
	Z(7,3)=0.05	ANL	72
	Z(8,3)=0.02	ANL	73
	W(11,3)=0.0	ANL	74
C	L=ANIMAL TYPE,K=POPULATION CATEGORIES	ANL	75
	DO 30 L=1,4	ANL	76
	HRVSP(L)=1.	ANL	77
	HRVST(L)=1.	ANL	78
	SPAC(L)=0.	ANL	79
	SPAS(L)=0.	ANL	80
	SPAP(L)=0.	ANL	81
	SPAR(L)=0.	ANL	82

SPAA(L)=0.	ANL	83
SAAP(L)=0.	ANL	84
HUMUS(L)=0.	ANL	85
TOTSF(L)=0.	ANL	86
IF (RR(L).EQ.0.0) GO TO 30	ANL	87
DO 20 K=1,8	ANL	88
Z(K,L)=Z(K,1)	ANL	89
IF (L.GT.2) Z(K,L)=Z(K,3)	ANL	90
C W(17,IN)=MATURE WT. OF HERBIVORE (KG.)	ANL	91
W(17,L)=RR(L)*W(17,1)	ANL	92
C W(K,IN)=CATEGORY WT. COMPARED TO BEEF CATTLE.(KG.)	ANL	93
W(K,L)=RR(L)*W(K,1)	ANL	94
C M(K,IN)=METABOLIC HEIGHT (KG.)	ANL	95
M(K,L)=(RR(L)*W(K,1))*0.75	ANL	96
C R(K,IN)=RUMEN CAPACITY (KG.)	ANL	97
R(K,L)=0.08*M(K,L)	ANL	98
C S(K,IN)=RUMEN FILL (KG/DAY)	ANL	99
S(K,L)=R(K,L)	ANL	100
C U(K,IN)=DIGESTIBLE DRY MATTER (KG/DAY)	ANL	101
U(K,L)=R(K,L)	ANL	102
C P(K,IN)=MICROPROTEIN LEVEL IN RUMEN PER-GROUP,GRAMS	ANL	103
P(K,L)=200.0*RR(L)	ANL	104
20 CONTINUE	ANL	105
30 CONTINUE	ANL	106
DO 40 I=1,8	ANL	107
DO 40 J=1,4	ANL	108
Q(I,J)=0	ANL	109
V(I,J)=0	ANL	110
40 CONTINUE	ANL	111
DO 60 J=1,4	ANL	112
IF (RR(J).EQ.0.0) GO TO 60	ANL	113
DO 50 L=1,22	ANL	114
SNIT(L)=0.0	ANL	115
IF (RGC(L).EQ.0.0.OR.PUTZD(J,L).EQ.0.0) GO TO 50	ANL	116
PNIT(L)=N2	ANL	117
SNIT(L)=NH	ANL	118
ONIT(L)=SNIT(L)	ANL	119
PP6(L)=1.0	ANL	120
50 CONTINUE	ANL	121
60 CONTINUE	ANL	122
DO 120 J=1,4	ANL	123
IF (RR(J).EQ.0.0) GO TO 120	ANL	124
DO 110 K=1,22	ANL	125
IF (RGC(K).EQ.0.0.OR.PUTZD(J,K).EQ.0.0) GO TO 110	ANL	126
PP6(K)=0.0	ANL	127
IPUTZ=PUTZD(J,K)	ANL	128
GO TO (70,80,90,100), 1PUTZ	ANL	129
70 SPUT(1)=SPUT(1)+1.0	ANL	130
GO TO 100	ANL	131
80 SPUT(2)=SPUT(2)+1.0	ANL	132
GO TO 100	ANL	133
90 SPUT(3)=SPUT(3)+1.0	ANL	134
100 CONTINUE	ANL	135
110 CONTINUE	ANL	136
120 CONTINUE	ANL	137
130 CONTINUE	ANL	138
IF (I1.EQ.0) RETURN	ANL	139
DO 160 L=1,22	ANL	140
A(L)=0.0	ANL	141
G(L)=0.0	ANL	142
D(L)=0.0	ANL	143
P4(L)=0.0	ANL	144
IF (RGC(L).EQ.0.0) GO TO 160	ANL	145
IF (SNIT(L).EQ.0.0) GO TO 160	ANL	146

IF (WND(L).LE.1.0) WND(L)=1.0	ANL	147
IF (B1(L).LE.1.0) B1(L)=1.0	ANL	148
IF (D1(L).LE.1.0) D1(L)=1.0	ANL	149
P4(L)=B5(L)/WND(L)	ANL	150
IF (P4(L).LE.-.05) P4(L)=-.05	ANL	151
P2=WND(L)	ANL	152
P3=D1(L)*WND(L)/B1(L)	ANL	153
B=P2+P3	ANL	154
A(L)=(1.-EXP(-0.167*B))	ANL	155
C G =FRACTION OF GREEN BIOMASS INGESTED	ANL	156
G(L)=3.0*P2/(3.0*P2+P3)	ANL	157
C D =FRACTION OF DRY STANDING BIOMASS INGESTED	ANL	158
D(L)=1.0-G(L)	ANL	159
C**** START *** CALCULATES NITROGEN CONTENT OF GREEN FORAGE SYNTHESIZED	ANL	160
IF (P4(L).GT.0.142) GO TO 140	ANL	161
PNIT(L)=10.9*P4(L)+1.436	ANL	162
GO TO 150	ANL	163
140 PNIT(L)=3.0	ANL	164
150 CONTINUE	ANL	165
C CALCULATES NITROGEN OF STANDING GREEN FORAGE	ANL	166
IF (PP6(L).GE.P2) PP6(L)=(P2**2)/PP6(L)	ANL	167
SNIT(L)=SNIT(L)*(PP6(L)/P2)+(1.0-PP6(L)/P2)*PNIT(L)	ANL	168
IF (SNIT(L).LT.N3) SNIT(L)=N3	ANL	169
C CALCULATES NITROGEN OF CONSUMED FORAGE	ANL	170
CNIT(L)=G(L)*SNIT(L)+D(L)*N3	ANL	171
PP6(L)=P2	ANL	172
WATER(L)=30.0*CNIT(L)	ANL	173
160 CONTINUE	ANL	174
DO 390 IN=1,4	ANL	175
IF (RR(IN).EQ.0.0) GO TO 390	ANL	176
K=IN	ANL	177
DO 170 L=1,22	ANL	178
IF (PUTZD(K,L).NE.4.0) GO TO 170	ANL	179
Q10=0.0	ANL	180
IXX=ICA(L)	ANL	181
IF (CUTA(L,IXX).NE.111-1) GO TO 170	ANL	182
IF (B1(L).LE.20.0) GO TO 170	ANL	183
Q10=(B1(L)-20.0+((B1(L)-20.0)/B1(L))*D1(L))*ACRES(L)*4047.	ANL	184
HRVST(K)=HRVST(K)+Q10	ANL	185
SPAS(K)=SPAS(K)+((Z3(L)+Z4(L))/(B1(L)+D1(L)))*Q10	ANL	186
SPAA(K)=SPAA(K)+(A2(L)/(B1(L)+D1(L)))*Q10	ANL	187
170 CONTINUE	ANL	188
SPAS(IN)=(SPAS(IN)+HRVST(IN)+SPAP(IN)+HRVSP(IN))/(HRVST(IN)+HRVSP	ANL	189
I (IN))	ANL	190
IF (SPAS(IN).LE.0.0) SPAS(IN)=0.0	ANL	191
SPAA(IN)=(SPAA(IN)+HRVST(IN)+SAAP(IN)+HRVSP(IN))/(HRVST(IN)+HRVSP	ANL	192
I (IN))	ANL	193
IF (SPAA(IN).LE.0.0) SPAA(IN)=0.0	ANL	194
DO 180 L=2,32	ANL	195
IF (YRGRZ(IN,L-1).EQ.0.0) GO TO 390	ANL	196
IF (A11.GE.YRGRZ(IN,L-1).AND.A11.LE.YRGRZ(IN,L)) GO TO 190	ANL	197
180 CONTINUE	ANL	198
GO TO 390	ANL	199
190 CONTINUE	ANL	200
C I1=CYCLE FOR (8) AGE CLASSES OF POPULATION	ANL	201
DO 380 I1=1,8	ANL	202
M(I1,IN)=W(I1,IN)**0.75	ANL	203
C Y(I1,IN)=INHALATION RATE (CU.M/DAY)	ANL	204
Y(I1,IN)=1.4*M(I1,IN)	ANL	205
C X(I1,IN)=BLOOD WEIGHT (KG.)	ANL	206
X(I1,IN)=0.07*W(I1,IN)**0.94	ANL	207
C C1=RUMEN CAPACITY (KG.)	ANL	208
C1=0.16*M(I1,IN)	ANL	209
DO 200 L=1,3	ANL	210

QSUM(L)=0.0	ANL	211
GTDR(L)=0.0	ANL	212
TNIT(L)=0.0	ANL	213
SACT(L)=0.0	ANL	214
SAIR(L)=0.0	ANL	215
QFRAC(L)=0.0	ANL	216
200 CONTINUE	ANL	217
O=C1-S(I1,IN)	ANL	218
IF (O.LE.0.001) O=0.001	ANL	219
DO 220 L=1,22	ANL	220
IF (PUTZD(IN,L).EQ.0.0) GO TO 220	ANL	221
K=PUTZD(IN,L)	ANL	222
GO TO (210,210,210,220), K	ANL	223
210 CONTINUE	ANL	224
Q10=(WND(L)*G(L)+D(L)*D1(L)*WND(L)/B1(L))*A(L)	ANL	225
QSUM(K)=QSUM(K)+Q10	ANL	226
GTDR(K)=GTDR(K)+G(L)*WND(L)*A(L)	ANL	227
TNIT(K)=TNIT(K)+CNIT(L)*Q10	ANL	228
S10=(WND(L)*G(L)*Z3(L)+D(L)*D1(L)*WND(L)*Z4(L)/B1(L))*A(L)/Q10	ANL	229
SACT(K)=SACT(K)+S10	ANL	230
IF (SACT(K).LE.0.0) SACT(K)=0.0	ANL	231
SA0=(WND(L)*G(L)*A2(L)+D(L)*D1(L)*WND(L)*A2(L)/B1(L))*A(L)/Q10	ANL	232
SAIR(K)=SAIR(K)+SA0	ANL	233
IF (SAIR(K).LE.0.0) SAIR(K)=0.0	ANL	234
220 CONTINUE	ANL	235
QFRAC(1)=1.0	ANL	236
IF (QSUM(2).EQ.0.0) GO TO 230	ANL	237
QFRAC(1)=.78	ANL	238
QFRAC(2)=.22	ANL	239
IF (QSUM(3).EQ.0.0) GO TO 230	ANL	240
QFRAC(1)=0.7	ANL	241
QFRAC(2)=0.20	ANL	242
QFRAC(3)=0.10	ANL	243
WATCAV=0.0	ANL	244
AJ=0.0	ANL	245
230 DO 240 K=1,3	ANL	246
IF (QFRAC(K).GT.0.0) AJ=AJ+1.0	ANL	247
WFRAC=(1.0-0.3*TNIT(K)/QSUM(K))	ANL	248
UP(K)=QFRAC(K)*O*WFRAC	ANL	249
WATCAV=WATCAV+WATFRAC	ANL	250
240 CONTINUE	ANL	251
C O =COMPUTES INGESTION RATE (KG/DAY)	ANL	252
O=UP(1)+UP(2)+UP(3)	ANL	253
N=0.0	ANL	254
GA=0.0	ANL	255
SPAC(IN)=0.0	ANL	256
SPAR(IN)=0.0	ANL	257
DO 250 K=1,3	ANL	258
IF (QSUM(K).LE.0.0) GO TO 250	ANL	259
SPAC(IN)=SPAC(IN)+UP(K)*SACT(K)/(QSUM(K)*O)	ANL	260
SPAR(IN)=SPAR(IN)+UP(K)*SAIR(K)/(QSUM(K)*O)	ANL	261
N=N+UP(K)*TNIT(K)/(QSUM(K)*O)	ANL	262
GA=GA+UP(K)*GTDR(K)/(QSUM(K)*O)	ANL	263
250 CONTINUE	ANL	264
IF (11.GT.1) GO TO 260	ANL	265
C N =ADJUSTS NITROGEN CONTENT TO ACCOUNT FOR INGESTION OF MILK	ANL	266
N=3	ANL	267
260 CONTINUE	ANL	268
K=IN	ANL	269
DO 270 L=2,32	ANL	270
IF (A111.GE.ONRNG(K,L-1).AND.A111.LE.ONRNG(K,L)) GO TO 280	ANL	271
270 CONTINUE	ANL	272
GO TO 380	ANL	273
280 CONTINUE	ANL	274

	HERD=ANIMAL(K,L-1)	ANL	275
C	DD1=DIGESTABLE INGESTA	ANL	276
	DD1=(1.-GA)*.45+GA*.7	ANL	277
C	H=DIGESTABLE ENERGY FROM INTAKE	ANL	278
	H=DD1*4300*0	ANL	279
	M2=0.0465	ANL	280
C****	AT THIS POINT THE MICROPROTEIN IN THE DIGESTABLE FRACTION IS COMPU	ANL	291
	IF (N.LT.0.6.AND.N.GE.0.0) M2=0.031*N	ANL	282
	IF (N.GE.0.6.AND.N.LT.1.8) M2=0.023*(N-0.6)+0.0186	ANL	283
C****	END ***	ANL	284
C	H2=GRAMS OF MICROPROTEIN IN RUMEN	ANL	285
	H2=H*M2	ANL	286
C	P(11,IN)=ACCUMULATION OF MICROPROTEIN IN RUMEN (M1=0.52/DAY)	ANL	287
	P(11,IN)=P(11,IN)+H2-M1*P(11,IN)	ANL	288
	IF (P(11,IN).LE.0.0) P(11,IN)=0.0	ANL	289
C	M4=THE RATIO OF MICROPROTEIN/METABOLIC WT.(G/KG)	ANL	290
	M4=P(11,IN)/M(11,IN)	ANL	291
C	F2=FERMENTATION DIGESTION RATE FRACTION (1/KG) (F1=0.04/KG)	ANL	292
	F2=F1*M4	ANL	293
C****	E=RUMEN EXIT RATE (FRACTION/DAY)	ANL	294
	E=E6+F2	ANL	295
	IF (E.GT.0.95) E=0.95	ANL	296
C****	END***	ANL	297
C	DD2=TOTAL POTENTIAL DIGESTABILITY	ANL	298
	DD2=U(11,IN)+DD1*0*(1.0-E+F2*E)	ANL	299
C	L1=UNDIGESTED FOOD	ANL	300
	L1=0*(1-DD1)+R(11,IN)-U(11,IN)	ANL	301
	IF (L1.LE.0.0) L1=0.0	ANL	302
C	L2=PASSED FOOD UNDIGESTED	ANL	303
	L2=(1-F2)*E*DD1*0+E*L1	ANL	304
	IF (L2.LE.0.0) L2=0.0	ANL	305
C	D3=COMPUTES CHANGE IN RUMEN DRY MATTER	ANL	306
	D3=0-E*DD2-L2	ANL	307
C	R(11,IN)=ACCUMULATION OF RUMEN DRY MATTER	ANL	308
	R(11,IN)=R(11,IN)+D3	ANL	309
	IF (R(11,IN).LE.0.0) R(11,IN)=0.0	ANL	310
C	U(11,IN)=ACCUMULATES DIGESTABLE RUMEN DRY MATTER	ANL	311
	U(11,IN)=(1.0-E)*DD2	ANL	312
	IF (U(11,IN).LE.0.0) U(11,IN)=0.0	ANL	313
C	S(11,IN)=RUMEN FILL	ANL	314
	S(11,IN)=R(11,IN)+P(11,IN)*0.001	ANL	315
	IF (S(11,IN).LE.0.0) S(11,IN)=0.0	ANL	316
C	X1=FRACTION OFFERMENTED ENERGY IN FORM OF FATTY ACIDS	ANL	317
	X1=0.747-0.15*(N-0.6)	ANL	318
	IF (N.LT.0.6) X1=0.747	ANL	319
	IF (N.GE.1.8) X1=0.591	ANL	320
C	BB=FATTY ACID ENERGY (KCAL)	ANL	321
	BB=F2*H*X1	ANL	322
C	E1=ENERGY FROM PASSED FOOD	ANL	323
	E1=0.25*L2*4300	ANL	324
C	E2=ENERGY FROM MICROPROTEIN	ANL	325
	E2=0.65*P(11,IN)*4.3*M1	ANL	326
C	E4=AVAILABLE ENERGY FOR GAIN	ANL	327
	HD=HERD	ANL	328
	HDD=(N5(IN)-HERD)	ANL	329
	A55=N5(IN)	ANL	330
	E4=BB+E1+E2-125.*M(11,IN)	ANL	331
	GSUPF=0.0	ANL	332
	IF (E4.GT.0.0) GO TO 290	ANL	333
	GSUPF=ABS(E4/4.3)*FSUPF(IN)*(HD/A55)*Z(11,IN)	ANL	334
	IF (HRVST(IN)+1..LT.GSUPF) GSUPF=HRVST(IN)-1.0	ANL	335
	HRVST(IN)=HRVST(IN)-GSUPF	ANL	336
C	W5=WEIGHT GAIN	ANL	337
	W5=0.0	ANL	338

IF (FSUPF(IN).EQ.0.0) W5=E4/1700.	ANL	339
GO TO 310	ANL	340
290 CONTINUE	ANL	341
C W3=RATIO OF HEIGHT/MATURE HEIGHT	ANL	342
W3=W(11,IN)/W(17,IN)	ANL	343
IF (W3.GE.1.0) GO TO 300	ANL	344
C E5=HEIGHT GAIN ADJUSTMENT FACTOR	ANL	345
E5=3.74+10.52*W3	ANL	346
IF (W3.LT.0.75) E5=3.74+5.26*W3	ANL	347
IF (W3.LT.0.5) E5=1.5	ANL	348
W5=E4/(E5*1700.)	ANL	349
GO TO 310	ANL	350
300 W5=0.0	ANL	351
310 CONTINUE	ANL	352
W(11,IN)=W(11,IN)+W5	ANL	353
C G1=GRAMS OF GREEN FORAGE CONSUMED	ANL	354
G1=GA*0*1000.	ANL	355
C D4=GRAMS OF DRY FORAGE CONSUMED	ANL	356
D4=(1.-GA)*0*1000.	ANL	357
C C2=TOTAL GRAMS OF FORAGE CONSUMED	ANL	358
C2=G1+D4	ANL	359
IF (C2.LE.0.0) C2=0.0	ANL	360
C C3=TOTAL PU INGESTED	ANL	361
C3=(HD/ASS)*C2*(SPAC(IN)+SPAR(IN))	ANL	362
C3=C3+GSUPF*(SPAS(IN)+SPAA(IN))	ANL	363
TOTSF(IN)=TOTSF(IN)+GSUPF	ANL	364
GSUPF=125.*M(11,IN)*FSUPF(IN)*HDD*Z(11,IN)	ANL	365
IF (HRVST(IN)+1..LT.GSUPF) GSUPF=HRVST(IN)-1.0	ANL	366
HRVST(IN)=HRVST(IN)-GSUPF	ANL	367
C3=C3+GSUPF*(SPAS(IN)+SPAA(IN))	ANL	368
TOTSF(IN)=TOTSF(IN)+GSUPF	ANL	369
C C4=SQ.METERS GRAZED/ANIMAL UNITS	ANL	370
C4=C2/(QSUM(1)+QSUM(2)+QSUM(3))	ANL	371
C M5=SQ.METERS GRAZED BY CATEGORY	ANL	372
M5=C4*Z(11,IN)*HERD	ANL	373
C M6=FRACTION OF AREA GRAZED	ANL	374
M6=HD*Z(11,IN)/(AA2(IN)*M7)	ANL	375
J=IN	ANL	376
DO 330 L=1,22	ANL	377
IF (PUTZD(J,L).EQ.0.0) GO TO 330	ANL	378
K=PUTZD(J,L)	ANL	379
GO TO (320,320,320,330), K	ANL	380
320 CONTINUE	ANL	381
Q10=(WND(L)*G(L)+D(L)*D1(L)*WND(L)/B1(L))*A(L)	ANL	382
Q00=G1*(Q10/QSUM(K))*(UP(K)/O)*M6	ANL	383
Q00=D4*(Q10/QSUM(K))*(UP(K)/O)*M6	ANL	384
Z3(L)=Z3(L)-Z3(L)*(Q00/B1(L))	ANL	385
Z4(L)=Z4(L)-Z4(L)*(Q00/D1(L))	ANL	386
A2(L)=A2(L)-A2(L)*(Q00+Q00)/(B1(L)+D1(L))	ANL	387
B1(L)=B1(L)-Q00	ANL	388
D1(L)=D1(L)-Q00	ANL	389
H1(L)=H1(L)+(Q10/QSUM(K))*(UP(K)/O)*L2*.75*1000./(AA2(IN)*M7)	ANL	390
IF (Z3(L).LT.0.) Z3(L)=0.	ANL	391
IF (Z4(L).LT.0.) Z4(L)=0.	ANL	392
IF (A2(L).LT.0.) A2(L)=0.	ANL	393
IF (B1(L).LT.1.) B1(L)=1.	ANL	394
IF (D1(L).LT.1.) D1(L)=1.	ANL	395
Z5(L)=Z5(L)+HUMUS(IN)*(Q10/QSUM(K))*(UP(K)/O)	ANL	396
330 CONTINUE	ANL	397
HUMUS(IN)=0.0	ANL	398
C6=0.0	ANL	399
DO 340 JK=1,22	ANL	400
IF (RGC(JK).EQ.0.0) GO TO 340	ANL	401
IF (SCTP(JK).EQ.0.0) GO TO 340	ANL	402

	IF (PUTZD(IN,JK).EQ.0.0) GO TO 340	ANL	403
	IF (PUTZD(IN,JK).EQ.4.0) GO TO 340	ANL	404
	IPUTZ=PUTZD(IN,JK)	ANL	405
	TSUMB=BI(JK)+DI(JK)	ANL	406
	FDIET=UP(IPUTZ)/SPUT(IPUTZ)	ANL	407
C	C5=GRAMS SOIL INGESTED/DAY	ANL	408
	C5=3.*W(11,IN)*20.0*FDIET/TSUMB	ANL	409
	IF (TSUMB.LT.20.0) C5=3.*W(11,IN)*FDIET	ANL	410
	Z1(JK,1)=Z1(JK,1)-C5*Z(11,IN)*HERD*Z1(JK,1)/(AA2(IN)*M7*3.0E04)	ANL	411
C	C6=COMPUTES PU ENTERING BLOODSTREAM/DAY FROM SOIL	ANL	412
	C6=C5*.001*Z1(JK,1)+C6	ANL	413
	HUMUS(IN)=HUMUS(IN)+.99*C5*Z1(JK,1)/(AA2(IN)*M7)	ANL	414
340	CONTINUE	ANL	415
C	Q(11,IN)=ACCUMULATION OF PU GOING TO PULMONARY REGION	ANL	416
	Q(11,IN)=Q(11,IN)+0.15*A1TT*Y(11,IN)	ANL	417
	Q(11,IN)=Q(11,IN)-Q(11,IN)*4.34E-04	ANL	418
	IF (Q(11,IN).LE.0.0) Q(11,IN)=0.0	ANL	419
C	L4=FRACTION OF PULMONARY GI BLOOD	ANL	420
	L4=Q(11,IN)*1.38E-04*0.001	ANL	421
	HUMUS(IN)=HUMUS(IN)+0.999*1.38E-04*Q(11,IN)/(AA2(IN)*M7)	ANL	422
C	L5=FRACTION OF PULMONARY BLOOD	ANL	423
	L5= (3.61E-03)*Q(11,IN)	ANL	424
C	C7=FRACTION OF AIR GI BLOOD	ANL	425
	C7=Y(11,IN)*A1TT*0.35*0.001	ANL	426
	HUMUS(IN)=HUMUS(IN)+.999*Y(11,IN)*A1TT*0.35/(AA2(IN)*M7)	ANL	427
C	C9=PU FROM GI-BLOOD FROM FOOD	ANL	428
	C9=C3*.001	ANL	429
	HUMUS(IN)=HUMUS(IN)+.999*C3/(AA2(IN)*M7)	ANL	430
	HUMUS(IN)=HUMUS(IN)*Z(11,IN)*HERD	ANL	431
C	V(11,IN)=PU IN BODY FROM ALL SOURCES	ANL	432
	V(11,IN)=V(11,IN)+L4+L5+C7+C9+C6	ANL	433
	IF (V(11,IN).LE.0.0) V(11,IN)=0.0	ANL	434
C	W(11,IN)=PU PER LITER IN MILK	ANL	435
	IF (11.0E.3) W(11,IN)=W(11,IN)+V(11,IN)*(Z(11,IN)/.9)*.001/X(11,IN)	ANL	436
1)		ANL	437
	IF (11.NE.8) GO TO 380	ANL	438
	IF (A111.NE.365) GO TO 380	ANL	439
	DO 350 K=1,7	ANL	440
	J=K-1	ANL	441
C	THE NEXT TWO STATEMENTS MOVE LIVESTOCK WT. AND ACCT. INTO NEXT AGE C	ANL	442
	W(8-J,IN)=W(8-K,IN)	ANL	443
	V(8-J,IN)=V(8-K,IN)	ANL	444
350	CONTINUE	ANL	445
	W(1,IN)=23.*RR(IN)	ANL	446
	W(9,IN)=0.0	ANL	447
	W(10,IN)=0.0	ANL	448
	W(12,IN)=0.0	ANL	449
	DO 360 K=3,8	ANL	450
C	W(9,IN)=TOTAL COUNTS/COW FOR 3-3 YEAR OLDS	ANL	451
	W(9,IN)=Z(K,IN)*V(K,IN)+W(9,IN)	ANL	452
	W(10,IN)=W(10,IN)+Z(K,IN)*V(K,IN)	ANL	453
C	W(12,IN)=TOTAL WEIGHT/COW AVE. 3-8 YEAR OLDS	ANL	454
	W(12,IN)=W(12,IN)+Z(K,IN)*W(K,IN)	ANL	455
360	CONTINUE	ANL	456
C	W(9,IN)=COUNTS/COW/BREEDING HERD	ANL	457
	W(9,IN)=W(9,IN)/(1-Z(1,IN)-Z(2,IN))	ANL	458
C	W(10,IN)=AVE. COUNTS/COW OF TOTAL HERD	ANL	459
	W(10,IN)=W(10,IN)+Z(1,IN)*V(1,IN)+Z(2,IN)*V(2,IN)	ANL	460
C	W(12,IN)=AVE. WEIGHT/COW OF TOTAL HERD	ANL	461
	W(12,IN)=W(12,IN)+Z(1,IN)*W(1,IN)+Z(2,IN)*W(2,IN)	ANL	462
C	W(13,IN)=PU/KG IN MUSCLE TISSUE OF HERD	ANL	463
	W(13,IN)=0.11086*W(10,IN)/W(12,IN)	ANL	464
C	W(14,IN)=PU/KG IN THE LIVER	ANL	465
	W(14,IN)=0.45*W(10,IN)/(0.052*W(12,IN)**0.7)	ANL	466

C	W(15,IN)=KG OF MUSCLE AVAILABLE TO POPULATION	ANL	467
	W(15,IN)=0.46*W(12,IN)*N5(IN)*P5(IN)	ANL	468
C	W(16,IN)=PU/KG IN BONE	ANL	469
	W(16,IN)=0.45*W(10,IN)/(0.075*W(12,IN))	ANL	470
C	V(1,IN)=PU IN NEW BORN CALVES	ANL	471
	V(1,IN)=W(9,IN)*0.001	ANL	472
	PRINT 490	ANL	473
	PRINT 520, (W(1,IN),I=1,8)	ANL	474
	PRINT 500	ANL	475
	PRINT 520, (V(1,IN),I=1,2)	ANL	476
	HRVSP(IN)=HRVST(IN)	ANL	477
	SPAP(IN)=SPAS(IN)	ANL	478
	SAAP(IN)=SPAA(IN)	ANL	479
	HRVST(IN)=1.0	ANL	480
	SPAS(IN)=0.0	ANL	481
	SPAA(IN)=0.0	ANL	482
	TOTSF(IN)=1.	ANL	483
	IF (AMOD(A11,XHERB).NE.0.0)GOTO370	ANL	484
	PRINT 410, XHERB	ANL	485
	PRINT 420	ANL	486
	PRINT 430	ANL	487
	PRINT 440, (RR(I),I=1,4)	ANL	488
	PRINT 450, (N5(I),I=1,4)	ANL	489
	PRINT 460, (AA2(I),I=1,4)	ANL	490
	PRINT 470, (FSUPF(I),I=1,4)	ANL	491
	PRINT 480, (P5(I),I=1,4)	ANL	492
	PRINT 500	ANL	493
	PRINT 520, (V(1,IN),I=1,8)	ANL	494
	PRINT 510	ANL	495
	PRINT 520, (Q(1,IN),I=1,8)	ANL	496
	PRINT 530	ANL	497
	PRINT 540, (W(1,IN),I=9,16),V(1,IN)	ANL	498
	370 CONTINUE	ANL	499
	380 CONTINUE	ANL	500
	W(11,IN)=0.0	ANL	501
	390 CONTINUE	ANL	502
	RETURN	ANL	503
C		ANL	504
	400 FORMAT (BF10.0)	ANL	505
	410 FORMAT (1H-,*MINANT OUTPUT YEAR OF OUTPUT = *,E9.3)	ANL	506
	420 FORMAT (1H0,*ANIMAL TYPE SIMULATED*)	ANL	507
	430 FORMAT (1H0,2X,*BEEF COW*,T14,*SHEEP *,T25,*DEER *,T36,*ELK	ANL	508
	1 *)	ANL	509
	440 FORMAT (2X,E9.3,T14,E9.3,T25,E9.3,T36,E9.3,T50,*MATURE WEIGHT RATI	ANL	510
	10 TO MATURE WEIGHT OF BEEF COW*)	ANL	511
	450 FORMAT (2X,E9.3,T14,E9.3,T25,E9.3,T36,E9.3,T50,*NUMBER OF ANIMAL U	ANL	512
	INITS /CATEGORY*)	ANL	513
	460 FORMAT (2X,E9.3,T14,E9.3,T25,E9.3,T36,E9.3,T50,*FRACTION OF REGION	ANL	514
	1 GRAZED*)	ANL	515
	470 FORMAT (2X,E9.3,T14,E9.3,T25,E9.3,T36,E9.3,T50,*FRACTION OF SUPPLE	ANL	516
	IMENTARY FEED*)	ANL	517
	480 FORMAT (2X,E9.3,T14,E9.3,T25,E9.3,T36,E9.3,T50,*FRACTION OF MUSCLE	ANL	518
	1 TISSUE AND ORGANS CONSUMED*)	ANL	519
	490 FORMAT (1H0,3X,*ANIMAL BIOMASSES,KG FOR AGES CLASSES W(1,IN),I =	ANL	520
	1 1,8)*)	ANL	521
	500 FORMAT (1H0,3X,*ACTIVITY ENTERING ORGANISM FROM ALL SOURCES (V(1,I	ANL	522
	IN),I = 1,8)*)	ANL	523
	510 FORMAT (1H0,3X,*ACCUMULATED ACTIVITY ENTERING FROM PULMONARY REGIO	ANL	524
	IN(Q(1,IN),I = 1,8)*)	ANL	525
	520 FORMAT (3X,E10.3,T14,E10.3,T26,E10.3,T38,E10.3,T50,E10.3,T62,E10.3	ANL	526
	1 ,T74,E10.3,T86,E10.3,T98,A8)	ANL	527
	530 FORMAT (1H0,*W(9,IN)*,T14,*W(10,IN)*,T26,*W(11,IN)*,T38,*W(12,IN)*	ANL	528
	1 ,T50,*W(13,IN)*,T62,*W(14,IN)*,T74,*W(15,IN)*,T86,*W(16,IN)*,T98,	ANL	529
	2 *V(1,IN)*)	ANL	530

540	FORMAT (1H0,E10.3,T14,E10.3,T26,E10.3,T38,E10.3,T50,E10.3,T62,E10.	ANL	531
	1 3,T74,E10.3,T86,E10.3,T98,E10.3,T110,E10.3)	ANL	532
	END	ANL	533

APPENDIX F

PLANT NUMBER POSITIONS FOR BIOLOGICAL TRANSPORT MODEL

WARM SEASON PLANTS

1. Corn and Sorghum
2. Annual Vegetables and Grains
3. Pasture Grasses
4. Fruit Trees
5. Pinon-Juniper
6. Deciduous Shrubs
7. Annual Grasses and Herbs
8. Warm Season Grasses
9. Evergreen Shrubs
10. Deciduous Trees

COOL SEASON PLANTS

11. Alfalfa
12. Annual Vegetables and Grains
13. Pasture Grasses
14. Douglas Fir
15. Ponderosa Pine
16. Deciduous Shrubs
17. Spruce-Fir
18. Cool Season Grasses
19. Annual Grasses and Herbs
20. Evergreen Shrubs
21. Deciduous Trees

APPENDIX G

CODE DOCUMENTATION OF TRU BIOLOGICAL TRANSPORT MODEL

I. INTRODUCTION

Code documentation of the TRU Biological Transport Model consists of three parts:

- addition of supplementary commentary into the computer code itself to clarify operation
- reworking of input-output options to accommodate specific needs of the user
- a description of process and state equations and boundary conditions

The commentary will be limited to identifying specific locations within the code which can be used in conjunction with this document to describe the operation of the model. Input-output options will be discussed by similar arrangement. In order to facilitate the description of such a lengthy code it will be necessary to follow the order of the code instruction as much as possible, starting with the main program and proceeding with the subroutines in the order presented in the code; it is also assumed that the reader will reference the operating instructions and variable library of the model for greater detail in some instances.

A. Program Plants (Inp, Out)

SECTION 1: Array Specification and Initial Input Requirements (statements PLA: 1-36)

All arrays have been previously defined;¹ most of them apply to the 21 plant type options selected for simulation. They are either defined as input or are initialized to a given value. The DATA statement (17) defines the number of days present in a given month. All input designated in this section is *required* for proper code operation. A zero input value suffices in all cases to exclude a certain plant from consideration or delete certain options. Other input pertains to climatic characteristics for the region of interest and for a reference site required to establish certain characteristics when records are not available for a given site. More information pertaining to climate and climatic input variables will be discussed in other portions of this document. The last input requirement in this section pertains to the simulation of TRU activity in the atmosphere for a chronic and/or an acute event. *CHRA*C is an intercept value for the first day of a chronic event while the values *CHRS*Y, *CHRE*Y, *CHRS*D, *CHRE*D are values referring to the extent (in years) for such an event, and to the number of days within the year when such an event shall take place, respectively. Either or both conditions can be made continuous for the entire simulation period or portions thereof by input specification. This information is used in establishing boundary conditions in duration (years and days within a year) and Activity (activity/m³ in air) in conjunction with *Function Airac* to be described in Section 3 of this document.

Inputs (CYR and DURC) are utilized to simulate acute air contaminating events (maximum of 64 days for any given year or combination of years (maximum of 16 yearly events)). TRU air concentrations for a given day on a given year are also determined by card input as described in the next section.

SECTION 2: Optional Input, Initialization, and Characterization of Root Zone (statements PLA: 37-148)

(Statements PLA: 37-45)

If an acute event involving TRU release to the atmosphere is to be simulated, then Input (CYR = IYR) specifies the selected year(s) for such events and the initial day of TRU release for each year are specified by arrays *YRCNT* and *DAIC*, respectively, for year and initial day of prescribed events. The array *AMAC* is required for storing via card input the TRU activity for each day of a given year as specified by Input (CYR = IYR; DURC = IDUR) and limited by the size of the array.¹ Activity can be specified in activity units or as count rate information.

(Statements PLA: 46-48)

The inputs (F1, W1, H1) relating to water holding characteristics of various soils are converted from percentage of held water to mm water, present in the upper 250 mm of soil by an appropriate factor ($2.5 = 250 \times P/100$, where P = percentage of water in soil, w/w).

(Statements PLA: 51-66)

The number of plants included in the simulation run and specific plants considered are identified for output through use of array *RGC*. Plants are also ranked according to order of appearance in this array.

(Statements PLA: 67-80)

Inputs (FFP, SDPTH, UPTKE, XPLNT, XHERB) are used to specify climatic, soil, output, and subroutine access information. *SOILF* has the equation:

$$SOILF = 0.632 / (1.0 - \text{EXP}(-0.004 * SDPTH))$$

where SDPTH = soil depth in mm, describes a function which at $250 < SDPTH$ calculates the fraction of actively absorbing root present in the upper 250 mm of soil. Values of SDPTH as small as 2 mm soil depth are used for calculating water utilization (Section 3). Soil depths shallower than 250 mm are assumed to contain all absorbing roots at that depth. Both *SOILF* and *SOILP*, its reciprocal, are used to determine other root characteristics to be described.

(Statements PLA: 81-86)

If different plants are to have different rooting depth, or if root depth information is available, such information may be entered via card input by specifying the depth for a given plant in the array *RCODE*.¹ The number of soil levels in 250 mm increments (IICDE) is determined from *RCODE*, and this value is used to input soil characteristics for each level of depth. The soil activity, *Z1*, the root fraction *ZF*, and the uptake coefficient *ZU* for each 250 mm soil increment

beneath a given plant is then entered by card input. The units for these parameters have been presented.¹

(Statements PLA: 87-104)

If all plants are to have the same rooting depth as specified by $SDPTH > 1.0$, then the number of soil increments are determined (IICDE) using this input value. RCODE is calculated from SDPTH so that the rooting depth for all plants in the simulation is the same. Furthermore, all values of $ZU = UPTKE$; all values of $Z1 = Y1$ as specified by card input.¹ The fraction of roots in each 250 mm soil level is determined by using equation (1) for each level present, and calculating the difference between successive levels. If there are only 2 soil levels specified (the uppermost being assigned to the 0-2 depositional horizon), then all of the root fraction is assigned to the second soil level as described previously. The uptake coefficient for the last level is adjusted if it is not totally occupied by roots; this is necessary because the code operates with whole values of soil levels. This fraction is determined by finding the fractional difference between RNDD and REEL in the code. The first level is also reserved for the (0-2) cm depth when soil level information is obtained from card input; both the root fraction ZF, and the uptake coefficient ZU are assumed equal to zero in this case. The TRU activity in the upper level Z1 is assigned a value depending on user needs; it is used for resuspension-deposition simulation of TRU, and as a driving function for movement of TRU into lower soil horizons to be described.

(Statements PLA: 105-146)

Arrays and other variables not used as input are initialized to zero or appropriate values.

(Statements PLA: 147-149)

Bud break and leaf drop for deciduous trees and shrubs is calculated by subtracting or adding one-half of the frost free period (FFP) for a given region to day number 210, respectively. The latter represents the approximate warmest calendrical day in most of the United States on a long-term average basis.

SECTION 3: Calendrical, TRU Air Concentration, Precipitation, Irrigation, Hydrological, Temperature Characteristics, and Initial Output (Statements PLA:)

(Statements PLA: 153-159)

If irrigated plants are to be simulated as determined by (RIRRC), then harvesting (CUTA), applied water (AWATA), and the time of water application (DIRA) are entered via card input. The first column of input for (CUTA) and (DIRA) are reserved for harvest, and planting date, respectively.

(Statements PLA: 160-163)

The random number seed (RANDN) is assigned an integer value (I7) for use in a DO loop. The mid range solar radiation value (A) is calculated as the difference of yearly maximum and minimum solar radiation ($T1 - T1$) divided by 2. The mid range monthly temperature, °F, (B) is calculated as the difference of average maximum and minimum monthly temperature, °F, ($T4 - T3$) divided by 2.

(Statements PLA: 164-165)

Initialization or seeding of the random number generator *RANDOM* is provided by iteration using a random number input (RANDN = I7) provided by the user. This scheme provides a different set of numbers used for climatological determinations described later in this section.

(Statements PLA: 166-167)

The years of simulation (Y2) is given an integer value (IJ) for use in a DO loop. A year counter (ICYR) is initialized to 1.

(Statement PLA: 168)

This statement marks the establishment of the requested simulation period in *years* as obtained through input (Y2 = IJ).

(Statements PLA: 169-173)

If an acute event is requested for any year or combination of years as specified in (YRCNT), then after such an event has been completed the index value (ICYR) is incremented by one to specify the next year when another event is to be recorded...etc.

(Statement PLA: 176)

This statement sets the initial year of simulation to zero. In most cases the program is allowed to proceed through the first year of the simulation before requesting any options to remove any extraneous influence caused by setting of initial conditions. Agricultural crop simulation is an exception to this rule.

(Statements PLA: 175-239)

Initial output is provided for the first year only. Included in this output is information concerning user options. If any or all subroutines are used, or if plants are entered in competition or succession, or if irrigation will be used, or if a chronic or contaminating event is simulated, the output will reflect user needs. Temperature, precipitation, and soil characteristics are printed under those headings. Chronic event and irrigation information will appear only if simulated in the model.

(Statements PLA: 240-248)

(AQ) is set equal to (I1) for use in daily output. Annual net production (WURAT) for specific plant, annual average temperature (TAV), annual cumulative precipitation (P1), and the real value of day number (K3) are set to zero. Day counter for irrigation (IRG) and day counter for harvesting schedule (ICA) are set to 2.

(Statement PLA: 249)

This statement marks the beginning of a calendrical year (365 days) for any given year of code operation.

(Statements PLA: 250-260)

The simulation of TRU air concentrations in a given region is facilitated by (AIRCA) for both a chronic and an acute event. If an acute event is requested, the TRU activity is entered from storage (AIRCA = AMAC) if the year (AI1) and the day number AIII) meet the specifications set forth in (YRCNT), (DAIC), and (DAIC + DURC). These operations may be circumvented by making the input value (CYR = 0.0).

If a chronic event is to be simulated singly or in combination with an acute event...i.e., then the function (AIRAC(CHRAC,AI1, AIII)) is executed provided the year (AI1) and the day number (AIII) are within the limits set forth by inputs (CHRSY, CHREY), and inputs (CHRSD, CHRED), respectively. This operation may be circumvented by zeroing these inputs. The summation of all events into AIRCA makes it possible to add these TRU activity contributions to the air with that contributed from resuspension of TRU from the surface of soils and plants to be discussed in another section of this report. The function AIRAC is provided by the *user* and substituted in the code at the appropriate location (1340-1343). A dummy function is provided in the code when this function is not being called.

(Statements PLA: 261-275)

The day number (III) within a given year (II) is assigned to one of the calendrical months, depending on its value. The day number for the end of each month is set at 21, 59, 90, 120, 151, 181, 212, 243, 273, 304, 334, and 365 days, respectively. February is assigned 27 days for all simulations and is not corrected for leap years. If the day number (III) equals the first of any month, it is assigned a month number (I) which is used in allocating monthly climate.

(Statement PLA: 277)

Unadjusted monthly precipitation is obtained by taking the product of monthly fraction (X) with the mean annual precipitation (R), and the conversion to mm.

(Statements PLA: 278-280)

Random number counter (Q8) and product of random number and number of days in given month (Q) are initialized to zero.

(Statements PLA: 281-289)

The number of precipitation events (NRE) in a given month (NDAY) are allocated to days within the month by selection of a random number from an *even* distribution (RANDOM), and taking the product of this number ($0 \leq \text{RANDOM} \leq 1$) with (NDAY); this value is allocated to (Q). In addition, (NRE) random numbers are selected, and summed (Q8) for use in precipitation allocation to the specific events determined in Q(L), ($1 \leq L \leq \text{NRE}$); precipitation allocation will be discussed later in this section. Finally, fractional days are converted to the nearest whole day as determined by (ABC) and allocated to (NN).

(Statements PLA: 290-295)

If any of the precipitation days (NN) are equal to each other, then another set of days is considered by reverting to statement PLA: 290 until (NRE) different precipitation days are selected.

(Statements PLA: 296-303)

Two random numbers (G4) and (G5) are selected from a *normal* distribution ($\mu = 0$, $\sigma^2 = 1$) for providing variations in monthly temperature and daily precipitation events to be described later in this section. Day counter (M) is incremented by 1.

(Statements PLA: 305-309)

Insolation in Langleys/day (AKK) is estimated by using the sum of a sinusoidal function with the minimum insolation (T1) for a given region. The function has limits between zero and the total difference ($A \times 2$) between minimum and maximum insolation values observed. The function also utilizes the lag factor (D) described previously. The photosynthetic efficiency (M1) is coupled to this function by a proportionality constant until saturation (0.45 g photosynthlate/g green biomass) is reached and remains at this value for insolation above 450 Langleys/day.

(Statements PLA: 311-314)

Mean daily temperatures ($^{\circ}\text{F}$) for a given region are estimated by using the sum of a sinusoidal function with the minimum daily temperature (T3). The function has limits between zero and total difference ($2 \times B$) between minimum and maximum temperatures observed. The function also uses the temperature lag factor (E) described previously. Regional mean temperatures are estimated by summing the temperature estimated for a reference site at a given elevation (RELV) with the product of the lapse rate (ALPSR) and the difference in elevation between reference site and the site of interest (RELV - G1) where (G1) is the elevation above sea level of the latter. The temperature is also corrected for the latitude difference (L3) between the reference and site of interest. This correction is set at $1^{\circ}\text{F}/^{\circ}$ latitude difference. All mean temperatures are converted to $^{\circ}\text{C}$ before making a final stochastic adjustment.

(Statements PLA: 315-319)

Variation of estimated monthly mean temperature is provided by generation of the normal random variable (G4, $\mu = 0$, $\sigma^2 = 1$) which is multiplied by an estimated standard deviation of the temperature statistic (TMXV). Any temperatures falling below 0°C are set equal to the latter. Finally, the mean annual temperature (TAV) is calculated using the estimated mean daily temperatures generated.

(Statements PLA: 320-334)

Precipitation (P) is allocated (NRE) times to a given month corresponding to a given day number M whenever it equals a selected day (NN) described previously. The ratio (Q/Q8) represents the fraction of the estimated monthly rainfall (DRMM) which is allocated to one of the (NRE) days selected for the event to occur. In addition, the precipitation is modified by adding to the initial allocation the quantity ($P * G5 * \text{PRCV}$) where (G5) is generated from a normal distribution as described for (G4), and (PRCV) is the estimated coefficient of variation for a precipitation event when it occurs in the region of interest. The total annual precipitation for a given year (P1) is estimated by summing all daily events. If temperature (T) is equal to zero, then P is expressed as snow accumulation (F7) which is converted to snowmelt (SNM) as a function of temperature (T). If the calculated (SNM) exceeds (F7), then (SNM) is set equal to (F7).

(Statement PLA: 335)

The potential evapotranspiration rate (E2) is a function of temperature (T).

(Statements PLA: 336-339)

Plant types (LPN) not simulated are excluded from the daily loop (RGC = 0). For the plants considered in the simulation the amount of soil water (WA) present is adjusted for additions due to precipitation (P) and/or snow melt (SNM). Also, air concentration of TRU (AAA) is adjusted for chronic and/or acute contributions (AIRCA).

SECTION 4: Irrigation Option, Soil Water Status, and Evapotranspiration Adjustment (Statements PLA: 341-356)

(Statements PLA: 341-347)

If irrigation is to be required for any plant (LPN) considered (RIRRC) then input amount (AWATA) is added to the existing soil water (WA) on a given day number (DIRA); the amount is added to the cumulative amount of precipitation (P1) for that year. The day counter (AIII) is then set to test the next day number for such an event (IRG).

(Statements PLA: 349-357)

The amount of soil water (WA) is set equal to the holding capacity of the soil (H) if additions exceed that value. The loss of soil water through evapotranspiration (EA) is set equal to the potential evaporation (E2) adjusted for the ratio of available soil water (WA) to the field capacity (F1) of the soil. If soil water is less than the wilt point (W1), (EA) is set to zero; if (WA) is greater than the field capacity, (EA) is set equal to (E2). Soil water losses are adjusted for soil depth with the factor (SOILF) described previously. The adjusted soil water (WA - EA * SOILF) for a given day (AIII) is set equal to the wilt point (W1) if losses render it less than that value. Also, the loss (EA) is adjusted to a value which would not allow soil water (WA) to drop below (W1). Finally, the variable (S1) is set equal to (EA), and (E4) to (EA) for use in the next section.

SECTION 5: Effect of Soil Moisture and Temperature on Growth, and Plant Growth Characteristics (Statements PLA: 358-479)

(Statements PLA: 358-366)

The determination for deciduousness in simulated plants is initialized (ISTP = 1) which specifies either evergreen trees and shrubs, or herbs, crops, and grasses which shed above ground parts during the off-season. The variable (SCTP) for a given plant (LPN) is initialized to simulate an herbaceous plant; the initial value (SAFP = 5) corresponds to a factor used for determining the effect of soil moisture on the photosynthetic rate of warm season plants. The effect of temperature on photosynthesis (E5) is also set for warm season plants at daily temperature (T) for day (AIII). The effect (E5) is determined through the use of several relationships depending on whether the temperature (T) is above or below the optimum (25°C) for that plant class. If the plant is of a cool season type (LPN > 10) then values of (SAFP), and (E5) are initialized for this plant set.

(Statements PLA: 368-475)

This subsection includes modification of any plant type (LPN) if it differs from the initial conditions set forth in the previous subsection; both warm and cool season plant types can be selected by proper matching of (LPN) with the access statement number in the computed (GO TO) Statement.

(Statements PLA: 476-478)

The constant (Q1) in the exponential term for determining the effect of soil moisture on photosynthesis (E7) is calculated using previously obtained values of (SAFP), (F1), and (W1). The value of E7 is limited to a value between zero and one as is (E5).

SECTION 6: Growth Form, Respiration, Photosynthesis, Biomass Allocation, Leaf Biomass, and Plant Life-Span Specification (Statements PLA: 479-718)

(Statements PLA: 479-499)

The biomass density of photosynthetically active biomass (WN1) is estimated initially as a function of (B11). A respiration biomass increment (ARP) given in increments of (WN1) is initialized at zero. This increment is added to (WN1) as part of the plant maintenance respiratory loading. The water utilization efficiency (WUTP) is initialized at 350. Also, the fractions of photosynthate translocated to above ground biomass (STRANS) and to below ground biomass (RTRANS) are set to 0.75 and 0.25, respectively. Photosynthesis (BAP) and respiratory (BCP) gates are initialized in the open condition(1). The constants (RFP, RXPP, and RAP) in the plant respiration equation are initialized at 0.01, 0.161, and 0.13, respectively. Finally, the mean life-span (HF) and the photosynthetic efficiency (PSE) are at 30 years, and 1, respectively; the latter value determines whether a given plant is a Calvin type plant (PSE = 1) or a more efficient Hatch-Slack plant (PSE = 0.5) which is set at twice the efficiency of the former; also, the biomass density (BP) of green and dead standing biomass is calculated for future use in the code. If a plant is of a cool season type (LPN > 10), then a new set of respiration coefficients (RXP, RXPP, RAP) are initialized for this category.

The (GO TO) statement directs the user to different growth strategies, depending on the plant simulated (LPN).

(Statements PLA: 500-707)

If the values of constants described previously in this section do not apply to a specific plant (LPN) simulated, then required constants are made within the statement subgroups designated. Statements PLA: 501-502, 509-510, 606-607 set limits on the occurrence of photosynthesis (BAP), and respiration (BCP) for harvested crops to correspond to planting (DIRA) and harvesting (CUTA) schedules. The first statement does not allow photosynthesis before planting day number or after the crop has been harvested. The second statement of each subgroup does not allow respiration to occur beyond the harvesting date, or for the initial 15 days after planting. Statements PLA: 520-524, 534-538, 549-553, 573-577, 584-588, 617-621, 631-635, 648-652, 659-663, 684-688, 695-699 quantify photosynthetic (WN1) and respiratory (ARP) biomass density for evergreen and deciduous tree and shrub types included within the code. The calculated photosynthetic biomass density maximum is limited to either all or one-half the calculated yearly running average productivity (TPGNW) for evergreen and deciduous woody plant types, respectively; calculated values of (WND) less than the latter are allowed in either case for

(WN1). The respiratory biomass density (ARP) is estimated as some multiple of photosynthetic leaf biomass density (WN1) for both deciduous and evergreen plant types, however, (ARP) is reduced by (WN1) during the dormancy period with limits set by (SFFP) and (EFP) for deciduous types. Finally, (ARP) for both plant types is limited to values equal to or less than the sum of above ground (B1) and below ground (R1) biomass densities which is of significance only during early plant growth.

(Statements PLA: 708-718)

The root respiration rate (AC) is set at one-third the above ground green biomass rate for herbaceous type plants and involves the constants (RFP, RXPP, RAP) and temperature (T) already described. The leaf area index (TLAI) is derived from (BP) which represents either the photosynthetic green biomass or in addition may include the dead standing component (D1) described previously. The respiratory biomass density for a given plant (RSBIO = ARP) is set at (WN1) if (ARP) is not utilized in the plant growth strategy. Also, the succession factor (SFAC) is set to one if either the succession module in the code is not accessed (RSCDE = 0) or if the plant type is agricultural and is not competing with other plants simulated (RSS > 12); other non-agricultural plants can also be excluded from succession by the latter control when (RSCDE = 1) for other plants within the simulation. Finally, if the plant type is deciduous (ISTP = 0), then the photosynthetic biomass density (WN1) is set to one outside the growing season.

SECTION 7: Photosynthesis, Respiration, Water Utilization Efficiency, Net Productivity, Photosynthate Allocation (Statements PLA: 719-745)

(Statements PLA: 719-735)

Gross daily areal photosynthesis (B5) is estimated from the product (WN1) * (BAP) * (M1) * (E5) * (E7) * CFAC * SFAC which has been described. Net daily areal photosynthesis is estimated by subtracting the respiratory or maintenance term from (B5): (WN1 + ARP) * (RFP) * (EXP(RXPP) * T) * (RAP) * (BCP) * CFAC * SFAC. The daily evapotranspiration rate (T5 = T5P * CFAC * SFAC) is estimated for comparison with the amount required (T6) for the potential net production estimated. The latter is estimated from an interaction term ($E5 * E7 \geq 0.01$) between temperature and soil water effects on photosynthesis, an estimated maximum water utilization efficiency (WUTP) for a specific plant, the relative photosynthetic efficiency; and the potential net photosynthesis (B5):

$$T6 = (C) * (PSE),$$

where

$$C = (WUTP)/(E5 * E7).$$

If the water evapotranspiration requirement (T6) exceeds the estimated evapotranspiration (T5), then (EWAT) is reduced to the maximum allowable under these conditions:

$$EWAT = (T5/T6) * (B5).$$

(EWAT) is further adjusted for competition with other plants in succession (SFAC) or for competition within the niche (CFAC) to be described in a later section of the report. If the potential

net photosynthesis is negative, (EWAT) is made equal to it (B5). Net production for a given year (WURAT) is obtained by summation of daily productivities (EWAT).

(Statements PLA: 736-745)

Photosynthate is transferred to above (B1) and below (R1) ground biomass compartments via increments (B5) and (B7), respectively, using (STRANS) and (RTRANS). However, if (EWAT) is negative, respiratory losses are made on a proportionality basis using (B1) and (R1) as factors. Eventual losses or gains of biomass are reflected in (B1) and (R1) for a given day (AIII) of the simulation.

SECTION 8: Biomass Losses due to Respiration, Harvesting, and Mortality; Humus Formation, and Control Options (Statements PLA: 747-980)

(Statements PLA: 747-748)

The effective life span for successional purposes (RSCF) is initialized to equal the average life span (HF) of a given plant type (LPN). The mortality loss factor (AP) for a given plant is based on the average life span (HF).

(Statements PLA: 749-750)

The computed (GO TO) statement controls access to specific plant biomass loss strategies.

(Statements PLA: 751-950)

For harvested crops and grasses of cool and warm season types (PLA: 754, 770, 774-788, 793-805, 855-867, 871-885, 888-900 mortality loss of above ground biomass (D3) is estimated at a value proportional to (B1) within a certain temperature regime specific to the plant type (LPN). If the value is outside, the temperature range (D3) is estimated from the product $(D3) * (R1/B1)$. (RD3) for pasture grasses and alfalfa are estimated from the mortality loss factor (AP) and (R1). Also, a respiration term $(AC) * (R1)$ is employed for these plant types to account for the uncoupling of maintenance biomass $(ARP = 0)$ for below ground portions in the photosynthesis equations described earlier. Crop harvesting losses at prescribed dates (CUTA) are estimated to augment (D3) by $(B1/10)$ and (RD3) by (R1). Also, TRU concentrations (Z3) and (Z2) are set to zero while (Z4) and (Z4R) are incremented by $(Z3/10)$ and (Z2), respectively. Grass harvesting losses reduce (B1) to 20 g/m² if the preharvest value of (B1) exceeds the latter initially. Proportional amounts of (Z4) and (D1) are also removed from preharvest values when applicable. Also, the values $(B1 = 1)$, $(R1 = 1)$, $(D1 = 1)$, and $(D3 = 0)$ are specified for crops outside of the growing season as specified by (DIRA) and (CUTA) for a given plant. Mortality loss schemes for perennial grasses (Statements PLA: 835-839, 926-930) are identical to those of pasture grasses. Annual grasses and herbs (Statements PLA: 827-832, 934-938) have mortality schemes similar to harvested crops, but differ in that (RD3) is augmented by the product $(AP) * (B1)$ for these plant types. The mortality increment (D3) for evergreen trees and shrubs (Statements PLA: 815-817, 843-845, 904-905, 909-911, 921-922, 942-943) is composed of an exponential needle or leaf loss involving (WN1) and a mortality loss $(AP) * (B1)$. The former loss assumes continuous leaf loss throughout a given year. Root mortality (RD3) is estimated from the products $(D3) * (R1/B1)$ as described previously for other plant types. Mortality increment (D3) for deciduous trees and shrubs (Statements PLA: 809-811, 821-823, 848-850, 915-917, 946-949) consists of the product $(B1) * (AP)$ except at the end of the frost-free period (EFFP) when (D3) is augmented by the total leaf biomass (WN1). Root mortality increment (RD3) is calculated as for evergreen plants of this type.

(Statements PLA: 951-956)

(D3) and (RD3) are set to zero if they exceed (B1) and (R1), respectively. The estimates (B1), (R1), (D1), and (RD1) are then adjusted on a daily basis by the mortality increments (D3) and (RD3).

(Statements PLA: 959-966)

Humus formation is estimated from a temperature (H2) and soil moisture (H3) effect on the decomposition rate of (D1) and (RD1). Both above ground produced humus (H1) and root humus (RH1) are augmented daily by the products (H2) * (H3) * (D1) and (H2) * (H3) * (RD1), respectively; conversely, (D1) and (RD1) are reduced by these amounts on a daily basis. Humus decomposition is estimated in daily increments (AC) * (H1) or (AC) * (RH1) depending on the type.

(Statements PLA: 967-972)

All estimates (B1, R1, D1, RD1, H1, RH1) are set to one if values fall below this value.

(Statements PLA: 973-977)

The initial year of the simulation (I1 = 0), plant (RGC = 3), minimum biomass (B1 = 1), and *Subroutine Forman* access statement for a specific year (XPLNT = I1) all control calling of *Subroutine Forman* for all plant types, but primarily for those of an herbaceous nature where daily stand structure is desired.

(Statement PLA: 979)

This statement marks the end of the daily plant module loop indexed by (LPN).

(Statement PLA: 980)

Access statement to *Subroutine Rmnant* depends on the value of (RHERB).

SECTION 9: Niche Competition, TRU Resuspension, Transport and Activity (Statements PLA: 981-1133)

(Statements PLA: 981-1000)

If similar plant types such as warm and cool season grasses are interacted (same value for RSS), then a weighted factor (CXFAC) is determined to control photosynthate production on a daily basis as described earlier. This factor is estimated from a consideration of the fractional daily growth rate $(B5 + B7)/(WND)$. The fractional daily growth rate

$$(B5 + B7)/(WND * RSCF),$$

is summed over all plants with equal $(RSS < 12)$ to obtain (CFAC) for day (AIII). (CFAC) is later equated to:

$$CFAC = (CXFAC)/(CFAC),$$

to obtain the desired factor. If production is negative ($B5 < 0$), then this interaction is circumvented.

(Statements PLA: 1003-1016)

Weighted average vegetative cover (CVTT) and air concentration (A1TT) are obtained by summing the products:

$(CCVV) * (CVMX)$, and $(A1) * (CVMX)$,

respectively, where (CCVV) is the estimated ground cover of a specific plant, (A1) is the immediate TRU air concentration surrounding the plant type, and (CVMX) is the fractional successional status of that plant to be described within the succession module. If succession is not considered (RSCDE = 0) or for the initial year (I1 = 0); both (CVTT) and (A1TT) are allowed to assume their specific values (CCVV) and (A1), respectively. A resuspension factor for TRU (RSUSP) is estimated from (CVTT) by an exponential equation:

$$RSUSP = 2.5 * EXP(-4.6 * CVTT) * 10^{-8};$$

CVTT is not allowed to become larger than one.

(Statement PLA: 1013)

A second plant loop is entered (LPN).

(Statements PLA: 1014-1021)

If (CVTT) and (A1TT) are not estimated by previous means, then they are allowed to assume values for a specific plant (CCVV) and (A1), respectively. (RSUSP) is estimated in the same manner as before.

(Statements PLA: 1022-1039)

The first soil layer (0-2 cm), (Z1), is depleted of TRU by two processes:

$(RSUSP) * (Z1)$,

and

$(0.693/700) * (Z1)$,

representing losses via resuspension of particles to the atmosphere, and that due to leaching of TRU to the next soil horizon, respectively. The surface layer is augmented by deposition of particles which are estimated to be proportional to (A1TT) described assuming a constant 450 m/day deposition velocity, and a 2 cm soil mixing layer; the second soil layer (Z1) is augmented by TRU leached from the top layer. The total amount of TRU resuspended from bare ground (A1Z) is estimated from (RSUSP), (Z1), and the estimated weight in grams of soil 2 cm deep and 1 m² area. On day numbers (AIII) when precipitation is absent (P = 0) the surface layer (Z1) is augmented by losses from plant surfaces (A2) and from the release of humus TRU to this layer. The loss rate of TRU from plant surfaces is based on an estimated 30-day retention half-life for particles under dry conditions. Air concentration (A1) is regenerated daily from contributions of (A2) surface humus (Z5), and that contributed from bare soil (A1Z); addition of TRU to air from other sources

(AAA) is also considered when applicable, and is discussed in a later section. The amount of surface deposition of TRU on plant surfaces is determined by the following relationships:

$$A2 = -(RSUSP) * (A2) - (0.693/30) * (A2) + (0.0021) * (A1TT) * (TLAI) * (0.67)$$

in which deposition is made dependent on the leaf area index of plant (LPN) and allows for 67% initial retention of deposited particles.

On day numbers when precipitation occurs ($P > 0$) resuspension is not allowed to occur, and deposition-retention characteristics are related to the amount of precipitation (P) in addition to other factors described earlier. Under these conditions the top layer of soil is augmented by as much as 0.3 of the deposit on plant surfaces ($A2$) being modified the value of (P) using the following relationship:

$$(0.3) * (1 - \text{EXP}(-0.6518P)).$$

Similarly, leach losses from the top soil layer into the second is also controlled by the amount of (P):

$$(0.01) * (1 - \text{EXP}(-0.6518P)).$$

Also, a minimum of 0.7 of ($A1TT$) is deposited on soil and plant surfaces, depending on the value of (P) as before.

(Statements PLA: 1041-1088)

The extent of root penetration into successive soil levels (RPNTP) is estimated with an exponential function relating the deepest penetration allowed in the code (7752 mm) to the total number of days since the start of growth ($A11P$). If annuals are simulated, then ($A11P$) is set to equal the respective day number in a given year ($A111$) for $RSCF \leq 9.0$.

The extent of root penetration (RPNTP) is used via the number of soil layers (IICDE) to determine whether TRU is absorbed by roots ($Z2$) from any given layer as denoted by the root gate (SP). The amount of TRU absorbed (RGAIN) is determined by the following relationship a specific soil level for a given plant (LPN) when ($SP = 1$):

$$RGAIN = (ZU) * (ZF) * (T5P) * (WND) * (Z1),$$

which is used to increment ($Z2$) on a daily basis and decrease the specific soil layer ($Z1$) by the same amount. However, each soil layer ($Z1$) is augmented by the mineralization of root humus TRU($Z5R$) at an estimated rate (AC) discussed earlier.

The movement of TRU from below ground biomass ($Z2$) to above ground portions ($Z3$) is estimated by (ADD) which is related to below ground translocation of photosynthate on a daily basis ($B7$) for a given plant; both positive and negative values of ($B7$) are considered to simulate exchange of TRU between above ($B111$) and below ground ($R111$) biomass components. Transport is controlled by small values of ($B1 \leq 1$), and maintenance biomass, ($T111 \leq B1$). Movement of TRU from roots ($Z2$) to above ground biomass ($Z3$) is estimated as:

$$(ADD) * (Z2) * (B111)/(B111 + R111),$$

and gain from (Z3) as:

$$(ADD) * (Z3) * (R111)/(B111 + R111).$$

The reverse is true of TRU transport to and from below ground. Above ground biomass (Z3) is corrected for mortality losses:

$$(Z3) * (D3/B1), \text{ as is that for below ground parts:}$$

$$(Z2) * (RD3/B1);$$

Both $(Z3 \geq 0)$; $(Z2 \geq 0)$ conditions must be satisfied for proper code operation. The TRU activity in dead standing biomass (Z4) is augmented from (Z3) losses and decreased by the product $(H2) * (H3) * (Z4)$ for a given plant type (LPN): Z4R is similarly calculated for dead standing root biomass. Changes of TRU in humus (Z5) is governed by losses due to respiration $(AC * Z5)$ and resuspension $(RSUSP * Z5)$; and is augmented by gains from (Z3) in its conversion to humus. Z5R is similarly estimated for below ground humus. (Z9) and (Z9R) are activity accumulators of TRU, having no other function than to sum up all TRU activity which has been recycled to the soil via humus of both above and below origin. (Z6) and (Z7) estimate the specific activity of TRU in above and below ground (B1, R1) biomass, respectively; (X8) and (Z8) estimate TRU accumulation factors for above and below ground components, respectively. In like manner (Z7P) and (Z7PR) estimate the TRU specific activity in dead standing above and below ground biomass components. Finally, the factors (A22) and (A23) estimate TRU specific activity and accumulation factor for surface deposition on plant leaf biomass (Z77) is the TRU accumulation factor for internal and external activity in above ground biomass.

(Statements PLA: 1089-1091)

After calculation of the total number of days elapsed (TP) since the beginning of the simulation, the decision to print factors generated on a daily basis is controlled by the user through the equality $(AQ = XPLNT)$ for any given year of the simulation (I1).

(Statements PLA: 1091-1117)

Daily output is provided if the year number (AQ) is equal to the year specified for daily output (PLNT). Headings provide variable names to conserve time and space (see variable library for definition of headings). Day number and plant number (LPN) are provided to facilitate easier reading.

(Statement PLA: 1118)

This statement marks the end of the daily loop (AIII).

SECTION 10: Running Average Yearly Production, Prorated Leaf Biomass, Plant Succession, Print Statements and Forman Access (Statements PLA: 1119-1257)

(Statement PLA: 1119)

The cumulative sum of yearly iterations (SYAV) is incremented by 1.

(Statements PLA: 1120-1133)

The next plant loop (LPN) in the program is used to calculate the fraction of potential leaf biomass (W11) from above ground biomass density (B11) which for woody plants (SCTP = 0) is compared with the current production of that plant (WUYAW); the latter is set equal to (W11) if (W11 < WUYAW). The sum of all yearly production estimates (WYAV) is divided by cumulative years of simulation (SYAV) to obtain the running yearly average biomass production (TPGNW ≥ 0.001) which is used to prorate leaf biomass for the following year of simulation. Plant cover for a given plant is estimated by:

$$CCCC = (1 - \text{EXP}(-1.54 * \text{TPGNW})) * C6,$$

although better estimates are obtained in *Subroutine Forman* for trees.

(Statements PLA: 1135-1180)

Two or more plants simulated under yearly interaction (RSCDE = 1) are treated in the succession module. Plants are ranked (RANK) according to their specific value of (STBR) which is a yearly running average of:

$$(R1 + B1 + D1 + RD1 + H1 + RH1)/(\text{RSCF})$$

plants with (RSS > 12) which are generally agricultural crops are not subjected to this treatment (CFAC = 1, SFAC = 1, RANK = 1). The highest value of (STBR = STBMX for RANK = 1) is used to determine a succession factor (SFAC) for all plants concerned. If agricultural crops are included as part of the simulation, individual plant acreage (CVMX) is used to calculate the total cover (CVAG) of all crops through the use of (ACRES) for such plants (RSS > 12). Caution should be used in allocating acreage assignments to that they do not exceed study area acreage. (CVMX) for a given crop plant is estimated as:

$$(\text{ACRES}) * (4047) * (\text{CCVV}) / ((3.07 \times 10^8 * \text{CVTT}),$$

for use in determining (RSUSP) and (A1TT) described earlier. (CVAG) is used to adjust succession factors (SFAC) for specific noncrop plants in the succession module, and will be described later in this section.

(Statements PLA: 1181-1221)

The succession factor for a given plant (SFAC) is initially allocated by the value of rank. Plant cover (CCVV) for each plant and a succession factor cover term (SFCT) which is cumulative of:

$$(1 - \text{SFCT}) * (\text{CCVV}).$$

The latter produces a series of factors according to (RANK) for all plants in the series. (SFAC) is normalized by (CCVV) for a given plant and is affected by the term:

$$(\text{STBR})/(\text{STBMX}).$$

The sum (SFFB) represents the sum of (SFAC). Another adjustment is made on SFAC:

$$SFAC = (SFAC)/SFFB$$

and the final adjustment is performed to account for crops cover:

$$SFAC = (SFAC) * (1 - CVAG);$$

the final summation (SFFC) is obtained. The latter is used to calculate the fractional cover contribution of each plant placed in competition:

$$CVMX = SFAC/SFFC,$$

which is then used to estimate (A1TT), and (CVTT) as described previously.

(Statements PLA: 1224-1236)

Yearly output is provided for each plant simulated in the model. Headings provide variable names to conserve time and space (see variable library for definitions of variable names). Plant number and year are included to facilitate easier reading.

(Statements PLA: 1238-1249)

Calculations for specific activity values (Z7P, Z77, A22, A23) are estimated for output.

(Statements PLA: 1253-1254)

Access to *Subroutine Forman* (RGC > 2) is optioned.

SECTION 11: Input Output Format Specifications (Statements PLA: 1260-1338)

B. Subroutine Forman

SECTION 1: Array Specifications, and Input Requirements (Statements FMG: 1-17)

All arrays in *Common*, and those in *Dimension* statements have been defined previously; the latter apply primarily to structural characteristics of a given plant (JK) for a minimum of 60 different diameter classes. They are derived from biomass and morphological variations among the 22 plant types (JK).

If access to this subroutine is desired, then the total number of yearly or daily output must be specified (TNWRT = 1), and a decision for access to Subroutine Forcut must be made (TBRM = 1), otherwise 0.0. In the diameter class interval size (XJ1), the density of dry plant material (C9), and the bole diameter to crown diameter proportionality constant (C6) must also be specified for a given plant (JK). The year(s) of specific output desired is stored in (WRSTR) for (TNWRT) specific years. If *Forcut* is accessed then the year(s) of specific management are stored in (DATCT) for (TBRM) specific years.

SECTION 2: Initialization of Variables, Diameter and Growth Estimates for First and Second Diameter Class (Statements FMG: 18-84)

(Statements FMG: 18-36)

If Forcut has been called for a given year (DATCT), then above ground biomass for the previous year (BBP) is reset to the resulting volume after FORCUT management or fire simulation has occurred and one year of regrowth allowed (B1). Program control is then *returned* to *PLANTS* for another year of regrowth before *Forman* is executed as before.

(Statements FMG: 37-44)

The decision to cycle a plant through on a daily (RGC = 3) or a yearly (RGC = 2) also determines whether the plant mortality coefficient (TCR) will be made equal to (1/365) or (RSCF), for plant (JK) respectively, to be described in a later section of *Forman*. The biomass density estimate (T1) for a given plant (JK) which is estimated to yield tree diameters in excess of 3" is calculated as:

$$T1 = (773) * (V8) * (1 - 0.5 CCVV) * (XJ1/2);$$

control is transferred to *PLANTS* until (T1 > V5). The *Forman* cycle counter (MIND) is incremented by one each passage of operation to the *Forman* subroutine beyond the initial *return* statement. The change (+, -) of biomass volume (G4) between current and previous year is estimated and adjusted for plant cover by the relationship:

$$G4 = (0.142 * B1 * V8 * (1 - 0.5 CCVV) / (SFAC * CFAC)) - BBP.$$

The actual volume of the stand (V4) is estimated at (0.142) * (B1) while the adjusted volume is related to (G4) as:

$$V5 = (0.142 * B1 * V8 * (1 - 0.5 CCVV) / (SFAC * CFAC)).$$

Finally, the minimum volume required for acceptance as a new class diameter (VTMBR) volume is estimated as:

$$V/2, \text{ for diameter class } (0 - XJ1)$$

$$Z * 77.3/V4, \text{ for all other diameter classes}$$

for a given plant (JK).

(Statements FMG: 45-70)

During the first access through *Forman* (M = MIND = 1), a number of structure variables are initialized; also the volume (V2) of a plant in the initial diameter class (0 - XJ1) is estimated as:

$$V2 = (0.3) * (0.035 * V8) * (2 * 2.54)^2.$$

The adjusted total volume (GTMBR) for the first diameter class is estimated as:

$$GTMBR = (T1 * \text{EXP}(-(1/RSCF) * (V5 - T1)),$$

and compared with the minimum volume. During the first cycling is *Forman* ($M = 1$) the virtual volume is used to simulate transport to the second diameter class ($XJ1 = 2 * XJ1$). In this instance the volume (Z) for the mean tree in the second diameter class interval is estimated as are the number of trees ($DTBR$); control is returned to the main program. In subsequent cycles ($M > 1$) through *Forman* estimation of the volume in the second diameter class is performed when all other classes with the exception of the first are considered. The first diameter class ($0 - XJ1$) volume ($GTMB$) is estimated as described for all ($M \geq 1$), and ($G4$) is used to drive the module. Finally, during all ($M \geq 1$) the difference between previous and current volumes of the first diameter class ($DGTMB$) is estimated for use in another section of *Forman*.

(Statements FMG: 71-84)

After setting ($VTMBR = GTMBR$) and determination of the number of trees ($DTBR$) in the first diameter class ($0 - XJ1$) for a given plant (JK), then a number of other variables are initialized for use in the next section.

SECTION 3: Tree Competition Factor, Tree Stand Characteristic Biomass Allocation by Diameter Class, and TRU Specific Activity Change (Statements FMG: 85-188)

(Statements FMG: 85-146)

Crown cover (COV), bole diameter (BAR), tree height (HGT), and diameter class competition factor (X) are all initialized on a yearly (or daily) basis for each cycle through *Forman* for all (N) diameter class present in the structure of plant (JK). After determination of the midpoint diameter for any diameter class (AN), the competition factor is determined in two steps:

$$X = (AN * C6 + V8)^2, \text{ and } X = (X) * (AN)^2 * (DTBR)$$

where the first term represents a crown diameter factor, and the latter a bole diameter factor for a given diameter class (N) of plant (JK). In addition, crown cover (COV), tree height (HGT), and bole diameter (BAR) are determined for the mean diameter tree (AN) in each diameter class (N), and standard and geometric means and deviations are estimated as ($CVMN \pm BSD$), respectively. Also, the crown and stem cover for each diameter class (N) are calculated as:

$$COV = (COV * DTBR) \text{ and } CTRB = DTBR * \pi * (BAR)^2$$

after regeneration of the initial values of (COV) and (BAR).

The sum of competition factors (X) for all diameter classes (N) is stored in ($C8$) as the sum of reciprocals ($C4$); the standard and geometric mean coverage for both crown and bole for the entire stand of (N) diameter classes is estimated as:

$$COVAV = (CVMN) * (TREES)/4047, \text{ BAAV} = (BMN) * (TREES)/4047, \text{ respectively,}$$

where ($COVAV \leq 1$), and ($BAAV$) have been redefined from previous use (Statements FMG: 137-138). Geometric means are also estimated for height ($BATR$), age ($AGAVE$), and stand TRU specific activity ($ACTAV$) from intermediate sums ($BAAV$), ($AGSUM$), and ($ACSUM$), respectively, where ($TREES$) represents the total number of trees of all diameter classes (N) in the stand except the first plant (JK). The above ground TRU activity ($TOTSA = Z3$) for plant (JK)

is used in conjunction with previous year activity (ZZ3) to estimate the change in TRU activity from one year to the next (ACTS) which is used in another section of Forman to be described.

(Statements FMG: 147-196)

For all ($X > 0$) with diameter classes ($L > 1$), the mean volume tree within each class is determined by averaging minimum ($AL9 - XJ1/2$) and maximum ($AL9 + XJ1/2$) tree volumes within a given class (L). The potential amount volume ($G3$) allocated to a given diameter class (L) is determined by the relationship:

$$G3 = (G4) * (X(L - 1)/C8),$$

and that which determines potential intra-class transport is estimated by:

$$G30 = (G4) * (X)/(C8).$$

If ($G4 > 0.0$), the potential volume increment for a given diameter class volume (GTMBR) is estimated as:

$$GTMBR = GTMBR + ((X(L - 1) - X(L))/(X(L - 1) + X(L)) * G30 + G3$$

If ($G4 \leq 0.0$) the following relationship is used to estimate volume change of (GTMBR):

$$GTMBR = GTMBR + (G4) * (GTMBR/V5) * (C8 - X)/C8,$$

for any diameter class ($L > 1$). The potential volume (GTMBR) is further adjusted for mortality losses by:

$$(GTMBR = GTMBR - (CCVV * GTMBR)/(TCR) * (C8 - X)/C8),$$

where ($GTMBR \geq Z$). ($V6$) is for the sum of all GTMBR for all volume classes. A residual volume ($V4M6$) is determined by difference from:

$$V4M6 = V5 - V6;$$

also ($C7 = VTMBR$), where ($L = 1$) is initialized for summing up volumes (GTMBR) for all ($L \geq 1$). For all GTMBR ($L > 1$) and ($C8 > X(1)$), the residual volume is added on proportional basis:

$$GTMBR = GTMBR + V4M6 * (1/X)/C4, \text{ for } (V4M < 0), \text{ or}$$

$$GTMBR = GTMBR + V4M6 * X/(C8 - X(1)), (V4M6 > 0),$$

depending on the value of (X) and ($C8$). The actual estimated volume is estimated as:

$$VTMBR = GTMBR * (V4/V5),$$

for all diameter classes ($L > 1$), and the total volume sum ($C7$) is also estimated for use in a later section of Forman. Finally, the number of trees (DTBR) for all diameter classes ($L > 1$) is calculated as:

$$DTBR = VTMBR/Z; (VVTM = VTMBR).$$

SECTION 4: Annual Tree Ring Estimate, Mean Age and TRU Specific Activity by Class Diameter; Output of Stand Estimates (Statements FMG: 197-282)

(Statements FMG: 197-217)

An annual running average radial growth for all trees (RINGT) is estimated by summing and averaging the product:

$$AL9 * (VTMBR/VVTM - 1.0)^{1/3} * DTBR$$

for all diameter classes ($L > 1$).

The TRU areal activity (VA) for a given diameter class ($L > 2$) is estimated as:

$$VA = (VTMBR * (SATB))/0.142,$$

and the difference between previous and current biomass volume (VDTMB) is estimated. For any values (VDTBM, G4) (VA) is augmented in two steps as follows:

$$VA = VA + |G4| * ACTS * X/C8, \text{ and}$$

$$VA = VA + SATB * VDTBM/0.142,$$

where ($VA \geq 0$) for a given diameter class ($L > 1$) and plant (JK). The areal TRU activity for the first diameter class is estimated as before for all diameter classes, and for all values (DGTMB, G4), (VA) is augmented by:

$$VA = VA + |G4| + ACTS * X/C8, \text{ and}$$

$$VA = VA + SATB * DGTMB/0.142,$$

for diameter class ($L = 1$) where ($VA \geq 0$) for plant (JK). The specific activity of the first diameter class ($L = 1$), (SATB) is estimated as:

$$SATB = VA/(VTMBR/0.142),$$

provided ($VTMBR > 0$). The total areal activity (TOTAC) is initialized to equal (VA) of the first diameter class for summation with other (VA) for ($L > 1$) to be described. However, if ($TOTSA = 1.0$) as described in Statement FMG: 216 then ($TOTAC = 1.0$) the ratio ($TOTSA/TOTAC$) is used for adjusting specific activity (SATB) in all diameter classes ($L \geq 1$) to provide materials balance in estimated (SATB) to be described.

(Statement FMG: 218-228)

The age (AGTB = AI1) in which a given diameter class ($L \geq 1$) is reached for a given stand of plant (JK), and the age (AI1) in which the previous diameter class ($L - 1 \geq 1$) is reached is used to estimate the average age of a specific diameter class ($L \geq 1$):

$$AATB = (AATB(L - 1) + AATB)/2.0,$$

provided ($AGTB > 0.0$). If ($AGTB = 0$), then average age for a specific diameter class is estimated: $2 * (AATB(L - 1))$. Also, the total number of years required for a diameter class ($L - 1$) to reach diameter class (L) is estimated by (GA), where $(GA(L - 1)) = (AGTB - AGTB(L - 1))$. If $(GA(L - 1) < 0)$, then it is estimated again as:

$$GA(L - 1) - AGTB(L - 1).$$

(Statements FMG: 229-236)

The specific activity ($SATB$) is reset to zero if ($VTMBR = 0.0$), otherwise, if a new diameter class is created ($SATB = SATB(L - 1)$) as an initial condition when ($VTMBR > 0$, and $SATB = 0$). The specific activity for all other classes ($L > 1$) is estimated as:

$$SATB = (SATB) * (TOTSATOTAC),$$

where ($SATB \geq 0.0$). The latter ratio ($TOTSATOTAC$) is bounded so that division by zero is avoided when the code is operated without TRU activity present.

(Statements FMG: 237-244)

When the year(s) of desired output are reached ($WRSTR = AI1$), then printed output is programmed for certain variables with *Forman*.

Output is provided here and is indicated as either daily or yearly output. If cutting and/or fire event is being simulated, then day numbers of specific managements are printed. Two groups of variables are printed (Statements FMG: 251 and 256) under the variable names (see variable library for definition of variables).

The adjusted specific activity for all diameter classes ($L > 1$) are estimated from the ratio ($TOTSATOTAC$) as described previously. Also, the mean volume ($VOLTR$) for trees in the stand ($L > 1$) and the total crown area for a given diameter class ($L > 1$) are estimated for output in Statements FMG: 272,273.

(Statements FMG: 276-282)

Previous year TRU activity ($ZZ3$) is reset to equal ($Z3$), and $SATB$ for diameter classes ($L \geq 1$) are estimated as before if output is not required during year ($AI1$) or ($XWRT = 0.0$). Finally, if Forcut management is desired ($TBRM > 0$), then program control is shifted to subroutine *Forcut*, otherwise, the program operation is returned to *PLANTS*.

SECTION 5: Input and Output Format Statements (Statements FMG: 283-299)

C. Subroutine Forcut

SECTION 1: Array Specification, Input Requirements, and Initialization of Variables (Statements FCT: 2-35)

All arrays in *Common* and those in *Dimension* statements have been defined previously. The latter apply to the type and extent of management operations or fire occurrence specified. If an event(s) is desired ($TBRM \geq 1$), then ($IBRM = TBRM$) management options are entered by card input for given plant type (JK), also, for the year(s) of occurrence ($DATCT = AI1$) for plant (JK)

and (TCUT = ITC) card input is required for removal of biomass via three diameter cut options (ACUT, BCUT, CCUT): for any event the diameter classes to be removed can be specified with a maximum of three management categories. Also, the fraction of biomass remaining within these categories is specified (RACUT, RBCUT, RCCUT) by card input. If a "Reverse-J" is to be simulated (ITC = 2), then control is shifted to a later portion of Forcut to be described; (ITC = 3) refers to a fire event.

SECTION 2: Management Events, Forest Structure, Biomass, and TRU Adjustments; Output (Statements FCT: 36-125)

Once specific diameter classes are chosen for removal or reduction (IA1, IB1, IC1, IA2, IB2, IC2) from a given stand for plant (JK), then for each category a timber reduction is performed as for the (A) category

$$VCUT = VTMBR * (1 - RACUT);$$

a reduction in the number of trees (DTBR) for a given diameter class (K) is estimated as:

$$DTBR = DTBR * (VTMBR - VCUT)/VTMBR.$$

The total biomass volume removed is determined by (VTOT) which is used for making further biomass and TRU adjustments to be described. If a fire event is simulated (ITC = 3) both (VTMBR) and (GTMBR) must be adjusted:

$$VTMBR = (VTMBR - VCUT) \text{ and } GTMBR = (VTMBR) * (V8) * (1 - CCVV/2)/(SFAC * CFAC).$$

As a result of a fire ($VCUT \leq VTMBR$) option the TRU activity in above ground humus ($Z5 = Z99$) is estimated as:

$$Z99 = Z99 + (0.9) * (VCUT) * (SATB)/0.142.$$

The TRU air activity (AA) is incremented by:

$$AA = AA + (0.1) * (VCUT) * (SATB)/(0.142 * 0.30),$$

also, the above ground TRU activity for live and dead portions are estimated as:

$$Z3 = Z3 - (SATB) * (VCUT)/0.142;$$

$$Z4 = Z4 + (0.2) * (SATB) * (VCUT)/0.141$$

Other biomass and TRU adjustments are:

$$D1 = (D1) * (C7 - VTOT)/C7$$

$$Z4R = (Z4R) = (Z2) * (VTOT/C7)$$

$$Z2 = (Z2) - (Z2) * (VTOT/C7)$$

$$WND = (WND) * (C7 - VTOT)/C7$$

$$TPGNW = (TPGNW) * (C7 - VTOT)/C7$$

$$R1 = (R1) - (R1) * (VTOT/C7)$$

$$B1 = (B1) * (C7 - VTOT)/C7.$$

Timber management for select diameter cutting (ITC = 1,2) have identical TRU activity and biomass adjustments with exception of above ground timber cuts (VTMBR - VCUT). They differ from a fire event by several adjustments:

$$Z4 = Z4 + (0.25) * (SATB) * (VCUT/0.141),$$

and neither (Z99) or (AA) are adjusted: the Reverse-J management (ITC = 2) differs from the other select diameter timber management (ITC = 1) in that the former is not specified by card input. The Reverse-J option removes all diameter classes (K) with diameters in excess of 25 inches ($AK \leftarrow 2K \geq 26$) and operates on the remaining diameter classes with an exponential removal scheme:

$$RVJ = (126) * (EXP(-0.197 * AK)) * (Z);$$

if $RVJ \leq VTMBR$; $VCUT = VTMBR = RVJ$. If select management is simulated (ITC = 1), then biomass volume is removed as described earlier for management via diameter selection via card input.

Output is provided in two places (Statements FCT:) with variable names as headings (see variable library for definitions of variable names). Finally, program control is *returned to PLANTS*.

SECTION 3: Input Format Statements (Statements FCT: 127-135)

D. Subroutine Rmnan

SECTION 1: Array Specification, Input Requirements, and Initialization of Variables (Statements ANL: 2-140)

(Statements ANL: 2-39)

All arrays have been previously defined.¹ The *Dimension* statements apply primarily to the characteristics of herbivores modeled, and to forage characteristics of native and agricultural plants (L). Other arrays of this type apply to population and grazing information for specific animal herds. During the initial access to *RMNANT* card input requirements are entered such as the mature weight ratio (RR) of a given animal type of beef cattle ($RR = 1.0$), otherwise ($RR = 0$) if a certain animal is not to be included within the simulation. Other input requirements are specific for each animal type (J); these include (P5), (N5), (AA2), and (FSUPF) which relate to herd size, grazing area, and consumption estimates (by humans) in a given region, and supplementary feed sources, respectively. Input is also required on annual grazing schedules (YRGRZ), range schedules (ONRNG), herd size for a given time interval (ANMAL), and the plants (L) included as forage (PUTZD) for animal type (J).

(Statements ANL: 40-110)

Initial values of nitrogen content in forage (N2, N4, N3) and rumen characteristics for beef cattle (M1, F1, E6) are set. Also, mature weight by age class (W), and population structure by age class (Z) are established for beef cattle, and the maximum area possible for grazing (M7) set. Other variables relating to TRU activity in or on forage (SPAC, SPAS, SPAP, SPAR, SAAP), and to amounts of available agricultural forage (HRVSP, HRVST) are also initialized.

(Statements ANL: 111-138)

If a ruminant type (L) is to be considered ($RR > 0$) then mature weight (W), metabolic weight (M), and other rumen characteristics and processes (R, U, S, and P) are adjusted for this animal type (L). TRU activity in a given population group of a specific animal type (Q), TRU entering this group from all sources ($V, I > 1$), and the TRU activity in newborn ($V, I = 1$) are all initialized at zero for animal type (J); the initial nitrogen content of photosynthate, standing biomass, and consumed forage for plant category (L), (PNIT, SNIT, and CNIT) are initialized to (N2) and (N4), respectively, ($CNIT = SNIT$). Finally, the native plants and agricultural crops used as forage (K) for animal type (J) are summed up (SPUT) into three categories depending on the preference (1,2,3) selected for this type of ruminant. The fourth preference ($PUTZD = 4$) is reserved for agricultural crops.

(Statement ANL: 139)

This statement marks the end of the initial access statement grouping described above. Subsequent access to *RMNANT* will shift control to statements below this value (ANL: 140)

SECTION 2: Nitrogen Content Determination, Grazing Schedules, Harvest TRU Content and Biomass (Statements ANL: 141-264)

(Statements ANL: 141-173)

If ($I1 > 0$) then the utilization efficiency (A) fraction of green biomass ingested (G), the fraction of dead standing biomass (D), and the relative above ground growth rate (P4) for plant type (L) are initialized to zero. If a plant is to be utilized as forage ($RGC > 0$, $PUTZD > 0$, $SNIT > 0$), then boundary conditions are set for leaf, above ground, and dead standing biomass (WND, B1, D1). The relative growth rate (D4) is estimated from the ratio ($B5(1)/WN1(L)$) where ($P4 \geq -0.05$). The total available biomass (B) is estimated from green (P2) and dry (P3) biomass estimates:

$$P2 = WND$$

$$P3 = (D1) * (WND/B1)$$

The utilization factor which adjusts the potential ingestion rate (A) is calculated for each plant (L) as:

$$A = (1 - \text{EXP}(-0.167 * B)).$$

The fraction of green biomass ingested (G) by a ruminant assumes a 3:1 preference for green (or live) biomass over dead biomass ingested (D):

$$G = 3 * P2 / (3 * P2 + P3)$$

$$D = 1 - G$$

If the relative growth rate ($P4 > 0.142$) then photosynthate nitrogen content (PNIT = 3.0), otherwise nitrogen content is estimated at:

$$PNIT = 10.9 * P4 + 1.436$$

where ($-0.05 \leq P4 \leq 0.142$). The total amount of nitrogen in consumed green forage is estimated as a weighted average of previous nitrogen content (SNIT) and photosynthate nitrogen content (PNIT) for a plant type (L):

$$SNIT = (SNIT) * (PP6/B2) + (1.0 - PP6/P2) * (PNIT),$$

if previous leaf biomass (PP6) is greater than current leaf biomass (P2), then:

$$SNIT = (SNIT) * (P2/PP6) + (1.0 - P2/PP6) * (PNIT);$$

in both estimates (SNIT) is not allowed to fall below nitrogen content in dead biomass (N3). The nitrogen content of consumed forage (CNIT) accounts for preferences by ruminants for live biomass:

$$CNIT = G * SNIT + D * N3,$$

after which (PP6) is reset ($PP6 = B2$), and the water content of the ingested forage (WATER) is estimated as:

$$WATER = 30 * CNIT.$$

(Statements ANL* 174-200)

If a specific animal herd (IN) is to be simulated ($RR > 0.0$), and the year number (AI1) falls within a specified grazing interval (YRGRZ), then a selection is made of all harvested crops (PUTZD = 4.0) for estimating the total amount of forage biomass available (HRVST) from these plants (L). When the day number (III) is one less than the harvesting date for a given crop (L):

$$CUTA = III + 1,$$

then available supplementary forage (HRVST) is incremented by the amount removed (Q10):

$$Q10 = (B1 - 20 + (20/B1) * D1) * ACRES * 4047$$

$$HRVST = HRVST + Q10$$

Furthermore, the total amount of TRU activity within the forage (SPAS), and on the surface of the forage (SPAA) is estimated:

$$SPAS = SPAS + (Q10) * (Z3 + Z4)/(B1 + D1)$$

$$SPAA = SPAA + (Q10) * A2/(B1 + D1), \text{ respectively.}$$

Finally, a weighted average TRU activity for current year harvest (HRVST) and for the previous year (HRVSP) is estimated from a knowledge of previous year activities in and on forage (SPAP, SAAP) for a given animal group (IN) over all plants (L):

$$(SPAS) = (SPAS * HRVST + SPAP * HRVSP)/(HRVST + HRVSP)^2$$

$$(SPAA) = (SPAA * HRVST + SAAP * HRVSP)/(HRVST + HRVSP)^2$$

(Statements ANL: 201-216)

Within the population group (II), metabolic weight (M), inhalation rate (Y), blood weight (X), and the rumen capacity (C1) are estimated for each age group (II) within an animal type (IN). Daily forage availability (QSUM), green forage biomass (GTDR), total nitrogen content (TNIT), TRU specific activity in plants (SACT), TRU specific activity on the surface of plants (SAIR), and fraction of total diet (QFRAC) for a given plant grouping (K) are initialized to zero. These variables apply to a grouping of plants into three preference schemes (PUTZD = 1,2,3) for use by animal group (IN) which are determined by card input as described earlier.

(Statements ANL: 218-234)

The potential ingestion rate is determined from the difference between the rumen capacity (C1) and the rumen fill (S) for the (II) age group of animal type (IN):

$$O = (C1) - (S), \text{ where } O \geq 0.001.$$

Forage plants are identified as to preference ($1 \leq \text{PUTZD} \leq 3$) and processed according to preference scheme (K). The total amount of biomass available within each preference scheme for forage is estimated as:

$$Q10 = ((WND) * (G) + (D * (D1) * (WND)))/(B1) * (A);$$

and accumulated as:

$$QSUM = QSUM + Q10$$

In similar fashion total green biomass available in preference category (K) is estimated by (GTDR):

$$GTDR = GTDR + (G) * (WND) * (A)$$

and the nitrogen content factor as:

$$TNIT = TNIT + CNIT * Q_{10}.$$

Also, the TRU specific activity factor in plants of preference scheme (K) is estimated as:

$$S_{10} = (WND * G * Z_3 + D * D_1 * WND * Z_4/B_1) * A/Q_{10}$$

and

$$SACT = SACT + S_{10}.$$

Finally, in similar fashion, the TRU specific activity factor on plant surfaces of preference scheme (K) is calculated as:

$$SAO = (WND * G * A_2 + D * D_1 * WND * A_2/B_1) * A/Q_{10},$$

and

$$SAIR = SAIR + SAO$$

All of the factor terms are reprocessed to obtain weighted average values of (TNIT), (SACT), and (SAIR) to be described in more detail below.

(Statements ANL: 236-248)

The food preference scheme is organized into three distinct classifications: If only one preference is entered, then

$$QFRAC(1) = 1, QFRAC(2) = 0.0, QFRAC(3) = 0.0$$

If two preferences are entered, then

$$QFRAC(1) = 0.78, QFRAC(2) = 0.22, QFRAC(3) = 0.0.$$

If three preferences are entered, then

$$QFRAC(1) = 0.7, QFRAC(2) = 0.20, QFRAC(3) = 0.10.$$

The total potential amount of biomass ingested from each preference category (K) is:

$$UP = (QFRAC) * (O),$$

for a given preference scheme (K). The estimated intake (O) is thus calculated as:

$$O = UP(1) + UP(2) + UP(3).$$

(Statements ANL: 249-264)

The estimated weighted specific activity in (SPAC) and on forage (SPAR) for a given animal group (IN) are calculated as:

$$SPAC = SPAC + (SACT) * (UP)/(QSUM * O)$$

$$SPAR = SPAR + (SAIR) * (UP)/(QSUM * O).$$

Also, the weighted average nitrogen content of forage (N) consumed by animal group (IN) is estimated as:

$$N = N + (UP) * (TNIT)/(QSUM * O),$$

and the fraction of green (live) forage (GA) consumed by animal group (IN) on day (AIII) is estimated as:

$$GA = GA + (UP) * (GTDR)/(QSUM * O).$$

Finally, for the first age group (IN = 1) nitrogen content is set at (N = 3) to account for milk consumption during the weaning period.

SECTION 3: Range Schedules, Rumen Function, TRU Uptake, Area Grazed (Statements ANL: 269-376)

(Statements ANL: 263-316)

If day number (AIII) falls within a grazing interval (ONRNG) for a selected grazing year (YRGRZ = AII) of a given animal type (IN), then for each age group (II), within this population rumen function is simulated for that day and year. Total digestible ingested fraction (DD1) of total consumed forage for animal (IN) is:

$$DD1 = (1 - GA) * (0.45) + (GA) * (0.7),$$

and the total digestible energy from intake (H) is estimated as:

$$H = (DD1) * (4300) * (O),$$

The microprotein fraction in the digestible fraction (M2) is set at:

$$M2 = 0.0456, (N > 1.8)$$

$$M2 = (0.031) * (N), (0 < N < 0.6)$$

$$M2 = (0.023) * (N - 6) + (0.0186), (0.6 \leq N \leq 1.8)$$

The total amount of microprotein formed from (DD1) in the rumen (H1) is estimated at:

$$H2 = H * M2$$

The accumulation of microprotein in the rumen assuming a loss rate of ($M1 = 0.52/\text{day}$) is:

$$P = P + H2 - M1 * P,$$

and the ratio of microprotein content to metabolic weight for a specific age group (II) of animal type (IN) is estimated as:

$$M4 = P/M,$$

where the units are (g/kg). Consequently, the fermentation digestion rate ($F2$) is estimated as:

$$F2 = F1 * M4,$$

where ($F1$) is set at ($F1 = 0.04$).

Hence, the total exit rate of dry matter from the rumen (E) is estimated as:

$$E = (E1 + F2),$$

where

$$(E6 = 0.25)$$

and

$$(E \leq 0.95).$$

Total potential digestibility of dry matter in the rumen ($DD2$) is estimated from current ($DD1 * O$), and previous (U) digestible content.

$$DD2 = U + (DD1 * O) * (1 - E + F2 * E)$$

Undigested food in the rumen ($L1$) is estimated at:

$$L1 = O * (1 - DD1) + R - U,$$

where (R) is the total rumen dry matter content; the total amount of food passed through the rumen undigested ($L2$) is estimated as:

$$L2 = (1 - F2) * (E) * (DD1) * (O) + E + L1.$$

The change in rumen dry matter content ($D3$) resulting from all processes is estimated as:

$$D3 = O - E * DD2 - L2,$$

and the change in rumen content for a given day is $R = R + D3$ ($R \geq 0$), and the change in digestible rumen content is:

$$U = (1 - E) * DD2.$$

Finally, the rumen fill (S) is estimated as:

$$S = (R) + (P/1000).$$

(Statements ANL: 317-376)

The fraction of fermented energy in the form of fatty acids (X1) for a given age group (II) of animal type (IN) is estimated as:

$$X1 = 0.747 = (0.15) * (N - 0.6) \quad (0.6 \leq N < 1.8)$$

$$X1 = 0.747 \quad (0 < N < 0.6)$$

$$X1 = 0.591 \quad (1.8 \leq N < 3)$$

The total amount of energy derived from fatty acids (BB) is estimated as:

$$BB = (F2) * (H) * (H1),$$

and energy derived from passed food (E1) is calculated as:

$$E1 = 0.25 * L2 * 4300.$$

Finally, energy derived from microprotein digestion (E2) is estimated as:

$$E2 = 0.65 * P * 4.3 * M1.$$

Hence, the net available energy (E4) for potential weight gain less the amount required for respiration equals:

$$E4 = BB + E1 + E2 - 125 * M,$$

for a given age group (II) of animal type (IN); also, the required amount of supplementary feed (GSUPF) is set:

$$GSUPF = (| E4 | / 4.3) * (FSUPF) * (HD/A55) * Z,$$

or equal to (HRVST - 1.0) if $GSUPF > HRVST + 1$, initially.

The weight gain (W5) of a given age group (II) is:

$$W5 = E4/1700, (E4 < 0, IN > 2)$$

$$W5 = 0, (E4 < 0, IN < 2).$$

However, for ($E4 > 0$), then the weight/mature weight ration (W3) is calculated as:

$$W3 = W/W(17,IN),$$

where the denominator is the mature weight for animal type (IN). A weight gain adjustment factor (E5) for added maintenance requirements is estimated as:

$$E5 = 0.0, (W3 \geq 1.0)$$

$$E5 = 3.74 + 10.52 * W3, (0.75 \leq W3 < 1.0)$$

$$E5 = 3.74 + 5.26 * W3, (0.5 \leq W3 \leq 0.75)$$

$$E5 = 1.5, (W3 < 0.5)$$

The total weight change for a given age group (II) is estimated as:

$$W = W + W5;$$

where the amounts of green (G1) and dry forage (D4) consumed by this age group are estimated at:

$$G1 = (GA) * (O) * (1000),$$

$$D4 = (1 - GA) * (O) * (1000);$$

and the amount of consumed forage (L2) is:

$$C2 = G1 + D4.$$

The amount of TRU ingested with forage (C3) is estimated from specific activities in and on forage (SPAC, SPAR), total intake (C2), and the number of animal units on range (HD), those on supplementary feed (HDD), and the total number of animal units (N5 = A55) of animal type (IN):

$$C3 = (HD/A55) * (C2) * (SPAC + SPAR).$$

The total also includes supplementary feed TRU activity which is added to the grazing component:

$$C3 = C3 + (HDD/A55) * (GSUPF) * (SPAS + SPAA).$$

The total amount of supplementary feed (TOTSF) required by age group (II) of animal type (IN) on a given day (AIII) is estimated as:

$$TOTSF = TOTSF + (GSUPF) * (HDD) * (Z),$$

where (Z) is the fraction of the animal herd (IN) in age category (II). For animals not on range which are maintained on supplementary feed, total TRU added by this herd fraction is estimated as:

$$C3 = C3 + GSUPF * (SPAS + SPAA),$$

where GSUPF is reset to $GSUPF = 125 * M * FSUPF$, provided $GSUPF > HRVST + 1$, otherwise $GSUPF = HRVST - 1.0$; (TOTSF) is incremented as before. Finally, the total number of square meters grazed (C4) by age group (II) for each animal unit within the category is estimated as:

$$C4 = (C2)/(TSUMB),$$

where (TSUMB) is the total amount of green and dry standing forage available. The total number of square meters grazed (M5) by an entire age category (II) is calculated as:

$$M5 = (C4) * (Z) * (HERD),$$

and the number of animal units/area grazed for each age category (II) is estimated as:

$$M6 = (HD) * (Z)/(AA2 * M7),$$

where (M7) is the largest total area of a region used for simulation purposes, whereas, (AA2) is the fraction of this region which is used by animal type (IN) for grazing purposes.

SECTION 4: Biomass and TRU Adjustments in Forage, TRU Transport through Lung Respiration, Excretion, and Soil Consumption (Statements ANL: 377-436)

(Statements ANL: 377-396)

Adjustments on TRU removal from above ground biomass consisting of both within forage (Z3) and surface TRU (A2), and also from dead standing biomass (Z4) are estimated from a knowledge of total consumption from the preference categories (PUTZD) as described earlier. Total consumption of forage (Q10) is:

$$Q10 = (WND * G + D * D1 * WND/B1) * (A),$$

and green forage consumed (QGO) is estimated as:

$$QGO = (G1) * (Q10/QSUM) * (UP/O) * (M6),$$

and forage consumed is:

$$QDO = D4 * (Q10/QSUM) * (UP/O) * (M6).$$

Adjustment of TRU activity in above ground biomass (Z3) is:

$$Z3 = Z3 - (Z3) * (QGO/B1); \text{ TRU in dead standing forage as:}$$

$$Z4 = Z4 - (Z4) * (QDO/D1), (Z3 \geq 0, Z4 \geq 0).$$

The adjustment of TRU on plant surfaces (A2) is estimated as:

$$(A2) = (A2) - (A2) * (QGO + QDO)/(B1 + D1), (A2 > 0).$$

Above ground biomass (B1), and dead standing above ground biomass (D1) are adjusted:

$$B1 = B1 - QGO, (B1 \geq 1.0),$$

and

$$D1 = D1 - QDO, (D1 \geq 1.0).$$

The amount of TRU in animal excretion (HUMUS) is added on to the humus activity (Z5) as:

$$Z5 = (Z5) + (HUMUS) * (Q10/QSUM) * (UP/O);$$

the humus compartment will be described below.

(Statements AN1: 398-414)

If a plant is of an herbaceous nature (SCTP = 1), and is not a cultivated crop (PUTZD = 4), then transport of TRU to animal type (IN) from soil is estimated from a knowledge of consumption estimates and biomass available. The fraction of the diet (FDIET) for a given forage plant (JK) within a preference scheme (PUTZD) is estimated as:

$$FDIET = UP/SPUT,$$

and the amount of soil consumed daily (C5) is estimated as:

$$C5 = 3 * (W) * (20) * FDIET/TSUMB,$$

where

$$(TSUMB - B1 + D1), (TSUMB \geq 20)$$

or

$$C5 = (3) * (W) * (FDIET), (TSUMB < 20.0).$$

The TRU activity in the first soil horizon Z1 is adjusted:

$$Z1 = Z1 - (C5) * (Z) * (HERD) * (Z1)/(AA2 * M7 * 3.0 E04).$$

The amount of TRU entering the bloodstream of animal type (IN) and age category (II) is estimated as:

$$C6 = (C5) * (0.001) * (Z1),$$

and the TRU excreted as feces is estimated at:

$$HUMUS = HUMUS + (0.999) * (C5) * (Z1)/(AA2 * M7);$$

the total amount of HUMUS produced by an entire age category (II) is estimated after all increments have been included.

(Statements ANL: 415-436)

The amount of TRU depositing in the pulmonary region (Q) of animal type (IN) is estimated as:

$$Q = Q + (0.15) * (A1TT) * (Y),$$

where (A1TT) and (Y) are air concentration of TRU, and the respiration rate of animal type (IN) and age group (II). The total amount lost daily is estimated as:

$$Q = Q - Q * 4.34 E - 04.$$

The fraction of TRU in the pulmonary regions which enters the bloodstream via the gut (L4) is estimated as:

$$L4 = (Q) * (1.38 E - 04) * (0.001), \text{ and (HUMUS) is incremented:}$$

$$HUMUS = HUMUS + (0.999) * (1.38 E - 04) * (Q)/(AA2 * M7).$$

The fraction of TRU which enters the bloodstream from the pulmonary region (L5) is estimated as:

$$L5 = (A1TT) * (3.61 E - 03) * (Q),$$

and the fraction of nonpulmonary deposits (C7) which enters the bloodstream via the gut for animal type (IN) and age category (II) is estimated as:

$$C7 = (Y) * (A1TT) * (0.35) * (0.001).$$

Again (HUMUS) is incremented:

$$HUMUS = HUMUS + (0.999) * (Y) * (A1TT) * (0.35)/(AA2 * M7).$$

The transport of TRU to the bloodstream via forage ingestion (C8) is estimated as:

$$C9 = (C3) * (0.001),$$

where (C3) is the weighted average specific activity of consumed forage described earlier; (HUMUS) is incremented:

$$HUMUS = HUMUS + (0.999) * (C3)/(AA2 * M7).$$

Also, (HUMUS) is estimated for the entire age group (II) as:

$$HUMUS = HUMUS * (Z) * (HERD).$$

The total amount of TRU entering an animal unit (IN) from all sources (V) is estimated as:

$$V = V + L4 + L5 + C7 + C9 + C6.$$

Finally, the concentration of TRU in milk ($W(11,IN)$ for animal type (IN) and age category ($II \geq 3$) is estimated as:

$$W(11,IN) = (W(11,IN) + V * Z/0.9) * 0.001/X,$$

where (X) is the blood weight for animal type (IN).

SECTION 5: TRU Activity in Herd, Print Options, Resetting of Variables (Statements ANL: 438-498)

(Statements ANL: 438-444)

At the end of each calendrical year ($AIII = 365$) each age group animal unit weight (W) and TRU activity content (V) are moved into the next age class.

(Statements ANL: 445-472)

The weight of a newborn of the first age class for a given animal type (IN) is estimated as:

$$W(1,IN) = (23) * (RR);$$

other variables are initialized for use in the following subsection.

Variable array for all ($L > 8$) is allocated to storage of specific TRU and biomass estimates and averages for a given animal type (K). Some of the variables involve some preliminary calculations ($W9$, $W10$, $W12$) before final estimates are made:

$$W9 = (Z) * (V) + W9$$

$$W10 = W10 + (Z) * (V)$$

$$W12 = W12 + (Z) * (W).$$

They either estimate the total TRU activity ($V * Z$) or total biomass ($W * Z$) for 3-8 year old categories.

The TRU activity/cow/breeding herd (3-8 year olds) is estimated as:

$$W9 = W9/(1 - Z(1,IN) - Z(2,IN)).$$

The TRU activity/cow/total herd (L-8 year olds) is:

$$W10 = W10 + Z(1,IN) * V(1,IN) + Z(2,IN) * V(2,IN).$$

The average weight/cow of the total herd is:

$$W12 = W(12,IN) + Z(1,IN) * W(1,IN) + Z(2,IN) * W(2,IN).$$

The mean TRU specific activity of muscle tissue in the herd is estimated as:

$$W13 = (0.11086) * (W10)/(W12); \text{ in the liver as:}$$

$$W14 = (0.45) * (W12)/((0.052) * (W12)^{0.7});$$

$$W16 = (0.45) * (W10)/(0.075 * W12).$$

The total amount of muscle tissue available to a human population in the region is estimated at:

$$W15 = (0.46) * (W12) * (N5) * (P5),$$

where (N5) and (P5) have been defined previously as number of animal units, and fraction of herd consumed in the study area, respectively. Finally, the TRU activity in newborn calves is estimated at:

$$V(1,IN) = (W9) * (0.001).$$

(Statements ANL: 473-484)

Output is provided here if (AIII = 365 and II = 8). Animal Biomass and Activity from all Sources are the headings and variables that will be printed.

(Statements ANL:)

Other variables are reset to current values:

$$SPAP = SPAS, SAAP = SPAA, HRVSP = HRVST,$$

while others are initialized to zero or an appropriate value. Output follows Statement ANL: only if (AI1 = XHERB) in the next section.

(Statements ANL: 488-498)

Output is provided here including input values that have not been printed previously (RR, N5, AA2, FSUPF, P5) in addition to (V)(I,IN), W(I,IN), I = 1,8, and W(I,IN), I = 1,16.

The concentration of TRU in milk is initialized to zero and control of *RMNANT* is returned to *PLANTS*.

SECTION 6: Input and Output Format Statements (Statements ANL: 505-532)

E. Function Airac (SACH,YR,DAY)

(Statements PLA: 1340-1343)

This function allows the user to substitute a function for estimating TRU air concentration (AIRAC) using an initial concentration (SACH), and a relationship between such activity and the year number (YEAR), and/or day number (DAY):

$$AIRAC = SACH$$

The relationship which is part of the program functions as a dummy (SACH = 0) or as a continuous activity function (SACH > 0).

APPENDIX H

INPUT REQUIREMENTS FOR TRU BIOLOGICAL TRANSPORT MODEL

I. INTRODUCTION

This document includes input instructions for operating the TRU Biological Transport Model (BIOTRAN). In addition, a variable library (Appendix D) has been included for both input and operating variables in the program to facilitate a better understanding of model operation and the various options which can be selected for a particular run. More detailed information concerning input variables, their source, and use are included in other portions of this report.

II. COMMENTS ON INPUT REQUIREMENTS

The input requirements for operating the code includes a number of optional input depending on a user's needs. The code is divided into five sections:

- 1) Main Program
- 2) Function Airac
- 3) Forman Subroutine
- 4) Forcut Subroutine
- 5) Rmnant Subroutine

The Main Program can be accessed independently of other code components depending on user needs. All other subroutines can be accessed only in combination with the Main Program. Both Rmnant and Forman subroutines can be accessed only with the Main Program. However, subroutine Forcut can be accessed only if Forman is called; the function Airac can be accessed with any combination of called subroutines. Finally, all subroutines and the Airac function can be accessed in a single run if desired. A brief description of subroutine capabilities will further clarify user options.

The Main Program contains the bulk of the transport model code, and with the exception of ruminant herd simulation, is a self-contained code. It contains all of the elements for climate simulation involving temperature, solar radiation, and precipitation. Also, all elements for simulating the growth of agricultural crops such as irrigation and harvesting schedules are included. All elements for simulating plant growth (Biomass density, g/m²), and TRU uptake are included within this routine. Finally, the elements for simulating plant succession and inter-niche competition are included there.

Function Airac is used to simulate concentration of activity in air: $A = f(d,y)$, where:

A = activity in arbitrary units...cpm, μCi , ...etc.

d = day number

y = year number

Any function of this type can be substituted in this section to tie into the Main Program.

The Forman subroutine contains the elements for determining the structure of a specific forest according to the following criteria:

- 1) by diameter class
- 2) by age group (not verified)
- 3) specific activity (not verified)

Specific input is required for a given type of forest. The subroutine can also be used in conjunction with grasslands and agricultural crops, although these options have not been verified or tested.

The Forcut subroutine contains all elements for forest management options based on diameter class. Any selected cutting option can be utilized including the simulation of a forest fire. The routine is interfaced with Forman and all other subroutines through the Main Program. Adjustments are made for removed activity and forest biomass as a result of the harvesting options employed.

The Rmnan subroutine contains all elements for simulating the growth of ruminant herds: beef cattle (also dairy), sheep, deer, and elk. The model utilizes biomass density estimates for native and agricultural forage crops (Main Program), and constructs a food preference and supplementary feeding scheme devised by the user. In addition to tracking TRU present in and on a given plant through selected tissues of the animal, the model also tracks inhaled TRU and TRU ingested with soil through the animal herd. Agricultural statistics on the number of animals grazing a given region, and the fraction of the area grazed by these animals during any month of the year are also available as input by the user. Output from this model consists of TRU concentrations in selected tissues for a given age group within the herd as well as averaged values such as that represented by marketed or consumed animal units. Also, the weight of each age category is available if desired by the user.

III. COMMENTS ON PROGRAM LOADING

Loading of the program deck depends on user requirements as noted in the input instructions. Some of the input is required for all runs independent of user needs. These include:

- 1) Insolation and monthly temperature characteristics for the region of interest
- 2) Precipitation and temperature characteristics of the site, and a reference site from which such information may be estimated
- 3) Edaphic and climatic features of the region in question such as elevation above sea level, frost-free period, soil holding capacity, wilting point, and field capacity

Some of this information can be obtained from field measurements, while other information can be obtained from Weather Bureau publications of the reference site. For example, Santa Fe, New Mexico, has been selected as the reference site for the study area (LASL) in question.

Some input is required for switching purposes to allow a variety of program capabilities as required, including which plants are to be simulated, and to allow choice of subroutines for a particular user objective. If agricultural crops are to be simulated, then a choice of irrigation information must be input if required. This includes irrigation schedules, harvests, and amounts of water applied.

If certain plants are competitors for the same "niche," such as cold season and warm season grasses, then input information may be entered to produce weighted yield for the competitors. Input requirements in such a situation require matching of input numbers for the plants in question to be described. A run of this type can include plants which are not included in this category.

Similarly, a decision to utilize the succession module located in the Main Program is determined by card input. The succession module operates with plant types on a yearly basis in contrast to the previous module which operates on a daily basis. Generally, the latter is applied to

perennial and annual grasses and herbs, while the succession module is applied to all perennials including grasses, shrubs, and trees. Finally, any combination of plants can be simulated with user objectives as to module use. Input options are also available for determining the fraction of the region grazed by animal herds, and for the growth of supplementary forage crops. These options are particularly important if the Rmnan subroutine is to be utilized.

Soil concentrations of TRU can be entered into the program as an option, as can soil depths, root fraction, and uptake coefficient for TRU. The model also provides for atmospheric contaminating events. One input capability is to provide measured air concentrations for a given period of time as described in the input instructions, or to substitute the Airac function with a chronic function required by the user. This instruction, however, *requires* program modification and caution should be used in function formulation. This function requires that either day number (1-365) or year number (or both) be included as part of the function. In addition, limits are provided for applications of such a function in terms of day and year number. Card input may also specify the year(s) of acute events as well as their duration; either or both options can be circumvented by card input.

Input specifications required for operation of the Forman subroutine if called are related to printed information or to management options if required. A user has the option of selecting up to 20 specific years of output of Forman information. The output can apply to daily as well as yearly output, depending on the type of plant simulated. Also, up to 32 different management events may be simulated through the use of Forcut subroutine as described in the input instructions on either a yearly or daily basis. Other input required for operation of this subroutine refers to plant characteristics such as the specific gravity of wood or plant bole diameter to crown diameter factor, and a relationship between plant biomass density and bole diameter for a given plant. Forman will operate on different plant types simultaneously, depending on user needs. Output from this subroutine gives stand structure by bole diameter, volume of timber by diameter class, the specific activity of the wood (averaged over total volume) for any diameter class, and the average age of a given diameter class. The latter three parameters are not verified by field observations at this time, and remain hypothetical.

Input specifications for operation of the Forcut subroutine relate specifically to timber management operations in forest ecosystems, although other plant types can be submitted for management. This subroutine allows the user a variety of management options through the simultaneous use of three plant clearing options. The user chooses diameter groups or ranges which are to be harvested or partially harvested and may simulate a heterogeneous or uniform management operation. In addition, the user may specify a typical Forest Service "RV-J" option as a management operation in conjunction with other options if desired. Removed biomass and TRU activity are tracked back into the Main Program and into all subroutines being accessed by the user to provide for stand regeneration. A forest fire option is included as part of the operation, which integrates with local air concentrations of TRU during and after such an event: output is not provided in this subroutine.

Input into the Rmnan subroutine includes the type(s) of animal units being simulated as herds or by simulated cow-calf or sheep operations. In addition to the number of animal units being considered and the available area for grazing, other input requires a knowledge of time schedules and number of animal units grazing during any given year of activity; the fraction of harvested animal units within the region that is consumed by residents is also provided by card input. The latter is used to calculate the weighted average concentration of TRU in edible tissues of these animals in relation to total tissue consumption by region residents. Also, the fraction of supplementary feed and plants utilized by a specific animal herd are entered via card input. The user is thus allowed to enter a forage preference scheme for a specific animal unit. Output from this subroutine has been discussed.

IV. INPUT INSTRUCTIONS FOR BIOLOGICAL TRANSPORT MODEL VIA CARD INPUT

Format for All Card Input (8F10.9) unless specified

CARDS MUST BE IN SPECIFIED ORDER

(required) 1 card: Insolation and Monthly Temperature Characteristics

DESCRIPTION OF FIELD

T1 = Minimum solar radiation, Ly/day received during the year

T2 = Maximum solar radiation, Ly/day received during the year

L1 = Lag period to maximum insolation, days

T3 = Minimum monthly daily temperature, °F, average for site based on average daily temperature

T4 = Maximum monthly daily temperature, °F, average for site based on average daily temperatures

L2 = Lag period to maximum temperature

(required) 1 card: Precipitation and Temperature Characteristics of Site

DESCRIPTION OF FIELD

TRE = Total rainfall events/month totaling more than 0.1"

TMXV = Maximum temperature variation, on a monthly basis

PRCV = Coefficient of variation for precipitation/event of reference site

RELV = Elevation, feet above sea level of reference site

ALPSR = Lapse rate, °F/ft from reference site

(required) 2 cards: Fraction of Precipitation Falling During a Given Month as a Function of Total Annual Precipitation

DESCRIPTION OF FIELD

X(1) = January fraction

X(2) = February fraction

X(3) = March fraction

X(4) = April fraction

X(5) = May fraction

X(6) = June fraction

X(7) = July fraction

X(8) = August fraction

X(9) = September fraction

X(10) = October fraction

X(11) = November fraction

X(12) = December fraction

(required) 1 card: Climatic Features and Soil Characteristics

DESCRIPTION OF FIELD

R = Annual precipitation, inches
G1 = Elevation of site, feet above sea level
L3 = Latitude relative to reference site (0.0, 1.0, -1.0)
F1 = Field capacity of soil, % H₂O
W1 = Wilting point of soil, % H₂O
H = Holding capacity of soil, % H₂O
Y1 = Activity of soil, activity/gram dry weight in soil
Y2 = Simulation interval, years

(required) 1 card: Selectors for Subroutines and Output

DESCRIPTION OF FIELD

RSCDE = (1.0 or 0.0) determines whether succession module is used(1) or ignored(0)
RHERB = (1.0 or 0.0) determines whether Rmnan Subroutine is called (1) or ignored(0)
RANDN = random number seed for a given run
FRMN = (1.0 or 0.0) specifies whether Forman Subroutine is called. This value is only for output purposes. Call of Forman Subroutine is controlled by RGC
ARIG = (1.0 or 0.0) specifies whether irrigation will be part of input. This value is only for output purposes. Irrigation is specified by RIRRC(22)
AICHE = (1.0 or 0.0) specifies whether niche competition will occur. This value is only for output purposes. Niche competition is specified by RSS
FRCT = (1.0 or 0.0) specifies whether Forcut Subroutine is called. This value is only for output purposes. Call of Forcut Subroutine is controlled by TBRM

(required) 3 cards: Selector for plants and calls of Forman Subroutine

DESCRIPTION OF FIELD

RGC(22) = selector for specific plants to be simulated. Plants are simulated by their position as they are listed on "Plant Number Positions for Biological Transport Model." Values for simulation are as follows:

0.0 = plant not simulated
1.0 = plant simulated, bypasses Forman Subroutine
2.0 = calls Forman subroutine on yearly basis
3.0 = calls Forman subroutine on daily basis

Yearly calls of Forman Subroutine are for structure determinations for forests and shrubs(2.0) on a yearly basis and for perennial and annual grasses(3.0) and herbs on a daily basis.

As an example, if Pinon-Juniper and Cool Season Grasses are to be simulated, then a value of 1.0, 2.0, or 3.0 must appear in the 5th and 18th field positions when the cards for RGC(22) are

punched. All of the rest of the fields must contain zeroes. Forman subroutine might be called on a yearly basis for Pinon-Juniper so that the value would be 2.0. For Cool Season Grasses a value of 1.0 would specify that the plant is being simulated but is not being routed through Forman.

(required) 3 cards: Irrigation

DESCRIPTION OF FIELD

RIRRC(22) = determines whether irrigation schedule for plant type will be part of input. Values of RIRRC are as follows:

0.0 = no schedule

1.0 = card input for irrigation required

As an example, if Alfalfa were to be simulated, irrigation would be specified with a value of 1.0 in the 11th field position. All other fields would contain zeroes. Card input must follow in its position. CUTA(22,8), AWATA(22,16), and DIRA(22,16) are the input variables needed for irrigation schedules. Only one set of cards is needed per plant.

(required) 3 cards: Niche Competition

RSS(22) = determines which plant groups are to be considered for niche competition for available land area. Values are as follows:

0.0 = bypasses niche competition module

1.0-12.0 = used to represent any plant group (same value for each) (2 or more plant types) which are to be adjusted for niche competition

13-22 = values used to bypass succession module for agricultural crops

As an example, if Cool and Warm Season Grasses are to be simulated and adjusted for niche competition, a value of 3.0 might be chosen and punched in the 8th and 18th field positions. The value must be the same for both plants. All other fields must contain zeroes or an appropriate value.

(required) 3 cards: Acreage

DESCRIPTION OF FIELD

ACRES(22) = determines acreage of land associated with specific plant group. Values for acreage are as follows:

0.0 = assumes area of specific grid of study area

xxx.xx = any other value specifies acres available for growth

Example: If a specific acreage is to be associated with a plant, it must be punched in the field relative to the plant. For Alfalfa, acreage would be punched in the 11th field position of ACRES(22).

(required) 3 cards: Soil Depth

DESCRIPTION OF FIELD

RCODE(22) = determines soil depth for specific plant types, mm. Values for soil depth are as follows:

0.0 = rooting depth via other input (SDPTH should be specified if RCODE is not utilized)

xxx.xx = rooting depth, mm

If a specific soil depth is simulated for Douglas Fir, for example, it would be punched in the 14th field position of RCODE(22). All other fields must contain zeroes or an appropriate value. The input value is calculated as the product of the number of soil levels desired times 250 mm: RCODE = 5750 for 23×250 mm soil levels, or 24×250 mm for some depth between 5751 to 6000 mm.

(required) 1 card: Chronic and Contaminating Events

DESCRIPTION OF FIELD

CHRACT = initial activity in atmosphere/m³ for chronic activity function (0.0 or a value greater than 0.0 required)

CYR = specifies the total number of years of an acute event (0.0 or value greater than 0.0 required)

DURC = duration of an acute event, days (0.0 or value greater than 0.0 required)

CHRSY = year of initial chronic contaminating event (0.0 or value greater than 0.0 required)

CHREY = year of chronic contamination terminated (0.0 or value greater than 0.0 required)

CHRSO = day of initial acute contaminating event (day number: 1.0-365.0 or 0.0 required)

CHRED = day of terminal contamination (day number: 1.0-365.0 or 0.0 required)

(optional) 2 cards: Required only if CYR is greater than 0.0, up to two cards input possible

DESCRIPTION OF FIELD

YRCNT(16) = determines specific years for application of an acute event. The years may be sequential or nonsequential, but equal to CYR. The value of CYR determines how many years are read so that if CYR = 5, then only one card is needed with 5 values.

(Optional) 2 cards: Required only if CYR is greater than 0.0, up to two cards input possible

DESCRIPTION OF FIELD

DAIC(16) = determines initial day of acute event for all years involved. (1.0-365.0) The value of CYR determines how many days are read so that if CYR = 8, then only one card is needed with 8 values.

(optional) 128 cards: Required only if CYR is greater than 0.0 and DURC is greater than 0.0, up to 128 cards input possible

DESCRIPTION OF FIELD

AMAC(16,64) = specifies amount of atmospheric activity/ m^3 on a given day (64 day event possible) for a given year (16 separate or continuous years possible). One set of cards is necessary for each year of CYR, up to 2 cards possible. If CYR = 3, DURC = 32, then 4 cards are needed for each year, 12 cards in all.

(required) 1 card: Climatic Edaphic, and Subroutine Options

DESCRIPTION OF FIELD

FFP = average frost-free period of site, days
SDPTH = soil depth, mm (equals 0.0 if input via other card input, RCODE(22)) for site
UPTKE = uptake coefficient, fraction/day/ m^2 transpiration/ m^3 , of TRU by plant
XPLNT = year for daily output of plant simulation
XHERB = controls output in Rmnant Subroutine on a daily basis. The value indicates the year(s) when such output will occur (modulus)

(optional) 88 cards: 4 cards per plant maximum

Format (8E10.3)

DESCRIPTION OF FIELD

Z1(22,32) = soil activity, activity/gram dry weight in given soil horizon

(optional) 88 cards: 4 cards per plant maximum

DESCRIPTION OF FIELD

ZF(22,32) = root fraction in given soil horizon

(optional) 88 cards: 4 cards per plant maximum

DESCRIPTION OF FIELD

ZU(22,32) = uptake coefficient for a radionuclide in a given soil horizon

(optional) 22 cards: Irrigation, Schedule required if RIRRC(22) is greater than 0.0. One card per plant.

DESCRIPTION OF FIELD

FORMAT (8F10.0)

CUTA(22,8) = harvesting schedules, day of year. The first column is reserved for final harvesting date. All unused fields must contain zeroes.

(optional) 44 cards: Required if RIRRC(22) is greater than 0.0. Two cards are needed for each plant irrigated.

DESCRIPTION OF FIELD

AWATA(22,16) = irrigation water applied, acres/inches, on specified date. All unused fields must contain zeroes.

(optional) 44 cards: Required if RIRRC(22) is greater than 0.0. Two cards are needed for each plant irrigated.

DESCRIPTION OF FIELD

DIRA(22,16) = irrigation schedule, day of year, when water is applied. DIRA(k,1) is reserved for planting date. Two cards are needed for each plant irrigated.

FORMAN SUBROUTINE

(required) 1 card per plant

DESCRIPTION OF FIELD

TNWRT(22) = indicates how many print outs of tree structure are required

TBRM(22) = indicates how many managed cuttings or events will be simulated. Maximum is 32 events (see TCUT(22,32) in FORCUT SUBROUTINE)

XJ1(11) = size of diameter class intervals(...etc. 2"-0.2")

V8(22) = taper regression coefficient, relating stem diameter to above ground biomass

C6(22) = crown diameter to bole diameter regression coefficient

C9(22) = wood specific gravity

(required) 3 cards per plant maximum

DESCRIPTION OF FIELD

WRSTR(22,20) = stores the years (days of specific output. The number of cards read depends on the value of TNWRT. If TNWRT = 5, then only one card is needed with only 5 values punched in the card. Filling in of zeroes is not needed.

(optional) 4 cards per plant maximum

DESCRIPTION OF FIELD

DATCT(22,32) = stores the years (days) of specific management generations: cutting, forest fire, etc. The number of cards read depends on the value of BRUM. If TBRM = 14, 2 cards are needed with only 14 values punched in the cards. Filling of zeroes is not needed.

FORCUT SUBROUTINE

(required) 4 cards per plant maximum

DESCRIPTION OF FIELD

TCUT(22,32) = specifies the type of cut or fire event. The number of cards read depends on the value of TBRM. If TBRM = 21, then 3 cards are needed with only 21 values punched in the cards. Filling of zeroes is not needed. TCUT is limited to 3 values:

- 1 = Choice Cut
- 2 = Reverse-J Cut
- 3 = Forest Fire

(required) 1 card per plant (for TCUT = 1,3)

DESCRIPTION OF FIELD

ACUT(22,1) = lower diameters selected for cutting "A" class cut selection
ACUT(22,2) = upper diameters selected for cutting "A" class cut selection
BCUT(22,1) = lower diameters selected for cutting "B" class cut selection
BCUT(22,2) = upper diameters selected for cutting "B" class cut selection
CCUT(22,1) = lower diameters selected for cutting "C" class cut selection
CCUT(22,2) = upper diameters selected for cutting "C" class cut selection

(required) 1 card per plant (for TCUT = 1,3)

DESCRIPTION OF FIELD

RACUT(22) = fraction of ACUT left standing

RBCUT(22) = fraction of BCUT left standing

RCCUT(22) = fraction of CCUT left standing

RMNANT SUBROUTINE

(required) 1 card

DESCRIPTION OF FIELD

RR(4) = indicates which of four animal types are simulated. Value = mature weight ratio to mature weight of beef cow, punched in col. 1-10 = beef cow, col. 11-20 = sheep, col. 21-30 = deer, col. 31-40 = elk. Value of 0.0 required if animal herd is not simulated.

(optional) 1 card per animal

DESCRIPTION OF FIELD

P5(4) = fraction of muscle tissue and organs consumed in study area produced in that region

N5(4) = number of animal units/herd

AA2(4) = fraction of region grazed by specific animal herd

FSUPF(4) = fraction of supplementary feed supplied by study area

(optional) 4 cards per animal

DESCRIPTION OF FIELD

YRGRZ(4,32) = Grazing intervals (years): Blank fields must be filled with zeroes: (10-20), (50-90), etc.

(optional) 4 cards per animal unit

DESCRIPTION OF FIELD

ONRNG(4,32) = days on range for day intervals (100-290), (150-300), etc. Blank fields must be filled with zeroes

(optional) 4 cards per animal unit

DESCRIPTION OF FIELD

ANMAL(4,32) = number of animals grazing during each interval. Blank fields must be filled in with zeros.

(optional) 3 cards per animal unit

DESCRIPTION OF FIELD

PUTZD(4,22) = plants utilized in feeding scheme of specific herbivore. Value range is from 0 to 4. A value of 0.0 implies nonutilization. A value of 1.0, 2.0, or 3.0 refers to preference of animal for given plant in descending order. Preference must be specified in the relative position of the plant. A value of 4.0 indicates plant is being used for supplementary feed. Blank fields must be filled in with zeroes.