Effect of nitrogen availability on the competition between plant species

A simulation study

J.G. Conijn

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Centre for Agrobiological Research (CABO)
P.O. Box 14, 6700 AA Wageningen, The Netherlands

Preface

This report is the result of a study at the Centre for Agrobiological Research (CABO) in Wageningen. It was conducted as part of my M.Sc. study Biology at the Agricultural University of Wageningen. It was carried out from September 1988 till April 1989 as practical work for the department of Theoretical Production Ecology and it was supervised by Frank Berendse and Wim Elberse of the CABO.

Wageningen, J.G. Conijn
May 1989.

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Samenvatting

Dit verslag bevat een computermodel, dat is ontwikkeld om het effect van de stikstofbeschikbaarheid op de dynamiek van plantesoorten in een mengcultuur te simuleren. Het doel van deze studie is de vraag te beantwoorden, welke plante-eigenschappen het succes van een soort bepalen in een nutriënt-arme danwel in een nutriënt-rijke omgeving.

Het model is geschreven in FORTRAN 77 en de rechthoekige integratie-methode is gebruikt met een integratie-tijdstap van één dag. Voor de parameterisatie van het model zijn de eigenschappen van twee grassoorten, die onder bemeste omstandigheden groeiden, Arrhenatherum elatius en Festuca rubra, gebruikt.

Twee groeibronnen, straling en stikstof, worden in het model verdeeld over de concurrerende soorten, waarbij is aangenomen dat alle andere groeibronnen niet limiterend zijn. De hoeveelheid straling die door een soort geäbsorbeerd wordt, wordt bepaald door zijn aandeel in de uitdoving van de straling. De uitdoving is een functie van de totale dagelijkse hoeveelheid aan globale straling en de bladoppervlakte indices van beide soorten, gewogen met hun extinctie-coëfficiënten. Drie horizontale bladlagen zijn onderscheiden om verschillen aan te geven in de vertikale verdeling van de bladoppervlakte index van de beide soorten. Een relatie tussen de hoogte en de bladoppervlakte index onder deze hoogte, is gebruikt om de bladoppervlakte index van een soort in elke laag te bepalen.

De beschikbare stikstof in de bodem wordt onder de soorten verdeeld, evenredig aan hun wortellengte indices, onder de voorwaarde dat de opname van een soort niet groter is dan zijn behoefte aan stikstof. De behoefte is gedefinieerd als de hoeveelheid stikstof die nodig is om de maximale stikstof-concentratie te bereiken.

Voor elke soort wordt de dagelijkse droge stofproduktie berekend door de hoeveelheid geäbsorbeerde straling te vermenigvuldigen met een efficiëntie-factor en vervolgens wordt deze produktie naar de verschillende plante-organen geälloceerd : wortels, bladeren, stengels en aren. De efficiëntie-factor hangt af van de gemiddelde stikstofconcentratie in de levende bladeren van een soort. De sterfte van wortels en bladeren wordt gesimuleerd door een verlies van droge stof van de levende biomassa. Hierbij wordt eveneens een deel van de stikstof die in de plant aanwezig is, verloren. Voor het bepalen van de wortellengte index en de bladoppervlakte index worden de drooggewichten van de levende wortels cq. bladeren vermenigvuldigd met de specifieke wortellengte respectievelijk het specifiek bladoppervlak.

Een validatie was nog niet mogelijk, de conclusies zijn daarom gebaseerd op computer-simulaties. Onder bemeste omstandigheden groeit Arrhenatherum ten koste van Festuca in een mengcultuur. De hoge beschikbaarheid aan stikstof stelt beide soorten in staat om hun stikstofbehoefte te bevredigen en om met een maximale efficiëntie te produceren. Arrhenatherum profiteert het meest van deze situatie, omdat het een grotere

bladoppervlakte index ontwikkelt en omdat het boven Festuca uit groeit. Arrhenatherum absorbeert het meest van de beschikbare straling, waarbij het slechts 10 % overlaat voor Festuca. De produktie van Festuca wordt erg laag, waardoor zijn stikstofbehoefte afneemt en de meeste stikstof blijft over voor Arrhenatherum.

De hoeveelheid droge stof die tijdens de simulatie-periode door sterfte verloren wordt, is bij benadering gelijk voor beide soorten. Door te maaien zal de hogere soort (Arrhenatherum) een groter deel van zijn spruit verliezen dan de lagere soort (Festuca). Het effect van maaien op de ontwikkeling van de soorten is nog niet in het model opgenomen.

De toename in levend drooggewicht van Arrhenatherum is uiteindelijk 16.4 keer groter dan dat van Festuca. Het verschil tussen beide soorten in de specifieke bladoppervlakte en in de extinctie-coëfficiënt heeft meer bijgedragen aan dit resultaat dan het verschil in de vertikale verdeling van de bladoppervlakte index. Festuca heeft aan het begin van de simulatie-periode een hoger spruit drooggewicht. Als beide soorten met gelijke hoeveelheden droge stof en stikstof in de spruit beginnen, dan zal aan het eind van de simulatie de toename in levend drooggewicht van Arrhenatherum 520 keer dat van Festuca zijn (vergelijk met 16.4). Het model is ook erg gevoelig voor de efficiëntie van de droge stofproduktie, waarvan is aangenomen dat het bij beide soorten gelijk is. Verder onderzoek wordt uitgevoerd om de extinctie-coëfficiënt en de efficiëntie van iedere soort aan de hand van veldgegevens te bepalen.

Summary

In this report a computer model is presented, which has been developed in order to simulate the effect of the nitrogen availability on the dynamics of plant species in a mixed stand. The aim of this study is to answer the question, which plant features determine the success of a species either in a nutrient-poor or in a nutrient-rich environment.

The model has been written in FORTRAN 77 and the rectangular integration method has been used with a time step of integration of one day. For parameterisation of the model, the plant features of two grass species, Arrhenatherum elatius and Festuca rubra, growing under fertilized conditions, have been used.

In the model two resources, radiation and nitrogen, are distributed among the competing species, assuming all other resources being non-limiting. The amount of radiation, absorbed by a species, is determined by its share in the extinction of radiation. The extinction of radiation is a function of the daily total of global radiation and the leaf area indices of both species, weighed by their extinction coefficients. Three horizontal leaf layers have been distinguished to account for differences in the vertical distribution of the leaf area index of both species. A relation between height and the leaf area index, beneith this height, has been used in order to determine the leaf area index of a species in each layer.

The available nitrogen in the soil is distributed among the species in proportion to their root length indices, under the condition that the uptake of a species does not exceed its demand for nitrogen. The demand has been defined as the amount of nitrogen which is needed to reach the maximum nitrogen concentration.

For each species the daily production of dry matter is calculated by multiplying the absorbed radiation with an efficiency factor and is then allocated to the various plant organs : roots, leaves, stems and ears. The efficiency factor depends on the averaged nitrogen concentration in the live leaves of a species. The mortality of roots and leaves is simulated by a loss of dry matter from live biomass. Via this path a part of the nitrogen which is present in the plant, is lost as well. In order to determine the root length index and the leaf area index, the dry weights of live roots cq. leaves are multiplied with the specific root length and the specific leaf area respectively.

A validation was not yet possible, therefore the conclusions are based on computer simulations. Under fertilized conditions Arrhenatherum grows at the expense of Festuca in a mixed stand. The high availability of nitrogen enables both species to satisfy their nitrogen demand and to produce at maximum efficiency. Arrhenatherum benefits most from this situation, because it develops a higher leaf area index and because it overtops Festuca. Arrhenatherum absorbs most of the available radiation, leaving only 10 % for Festuca. The production of Festuca becomes very low, which decreases its demand for nitrogen and most of the nitrogen is left over for Arrhenatherum.

The amount of dry matter which is lost during the simulation period through mortality , is approximately equal for both species. Through mowing the higher species (Arrhenatherum) will lose a greater part of its shoot than the lower species (Festuca). The effect of mowing on the development of the species is not yet incorporated into the model.

The increase in live dry weight of Arrhenatherum is eventually 16.4 times higher than that of Festuca. The difference between both species in the specific leaf area and in the extinction coefficient, has contributed more to this result than the difference in the vertical distribution of the leaf area index. At the beginning of the simulation, Festuca has a higher shoot dry weight. When both species start with equal amounts of dry matter and nitrogen in their shoot, the increase in live dry weight of Arrhenatherum will be 520 times that of Festuca at the end of the simulation (compare with 16.4). The model is also very sensitive to the efficiency of the dry matter production, which has been assumed to be equal for both species. Further research is being conducted to determine the extinction coefficient and the efficiency of each species from field data.

1. Introduction

The availability of nutrients has a great influence on the species composition of natural plant communities. This has been illustrated in a hayfield experiment at the Ossekampen (Van den Bergh, 1979 ; Elberse et al., 1983). In unfertilized plots the grass Festuca rubra was present at a frequency of 80-90% during 30 years , whereas Arrhenatherum elatius was almost absent in the same period . This situation became completely reversed when fertilization was applied (NPK : 160-52-332 kg ha^{-1} yr^{-1}). After 10 years Festuca rubra had disappeared and Arrhenatherum elatius increased towards a frequency of 50-60% (Figure 1).

From these different responses of plant species on nutrient availability the question arises, which plant features (morphological, physiological, etc.) determine the success of a species either in a nutrient-poor or in a nutrient-rich environment.

To answer this question a new experiment is being conducted at the Sinderhoeve with the following grass species : Festuca rubra, Anthoxanthum odoratum, Arrhenatherum elatius and Alopecurus pratensis. Festuca rubra and Anthoxanthum odoratum are characteristic for the low-nutrient plots at the Ossekampen, whereas Arrhenatherum elatius and Alopecurus pratensis are most frequently found in the high-nutrient plots. At the Sinderhoeve each species is grown in mono culture and in mixed cultures at two levels of nutrient availability : unfertilized and fertilized. Fertilization and mowing regime are carried out in a similar way as in the hayfield experiment at the Ossekampen. Data on the development of each species have been gathered in mono culture. In the mixed cultures only the standing biomass of each species, above mowing height, has been measured at times when the grass was cut.

The aim of this simulation study is to model the dynamics of plant species in mixture, using their characteristics measured in mono culture. Only radiation and nitrogen are assumed to be the limiting resources.

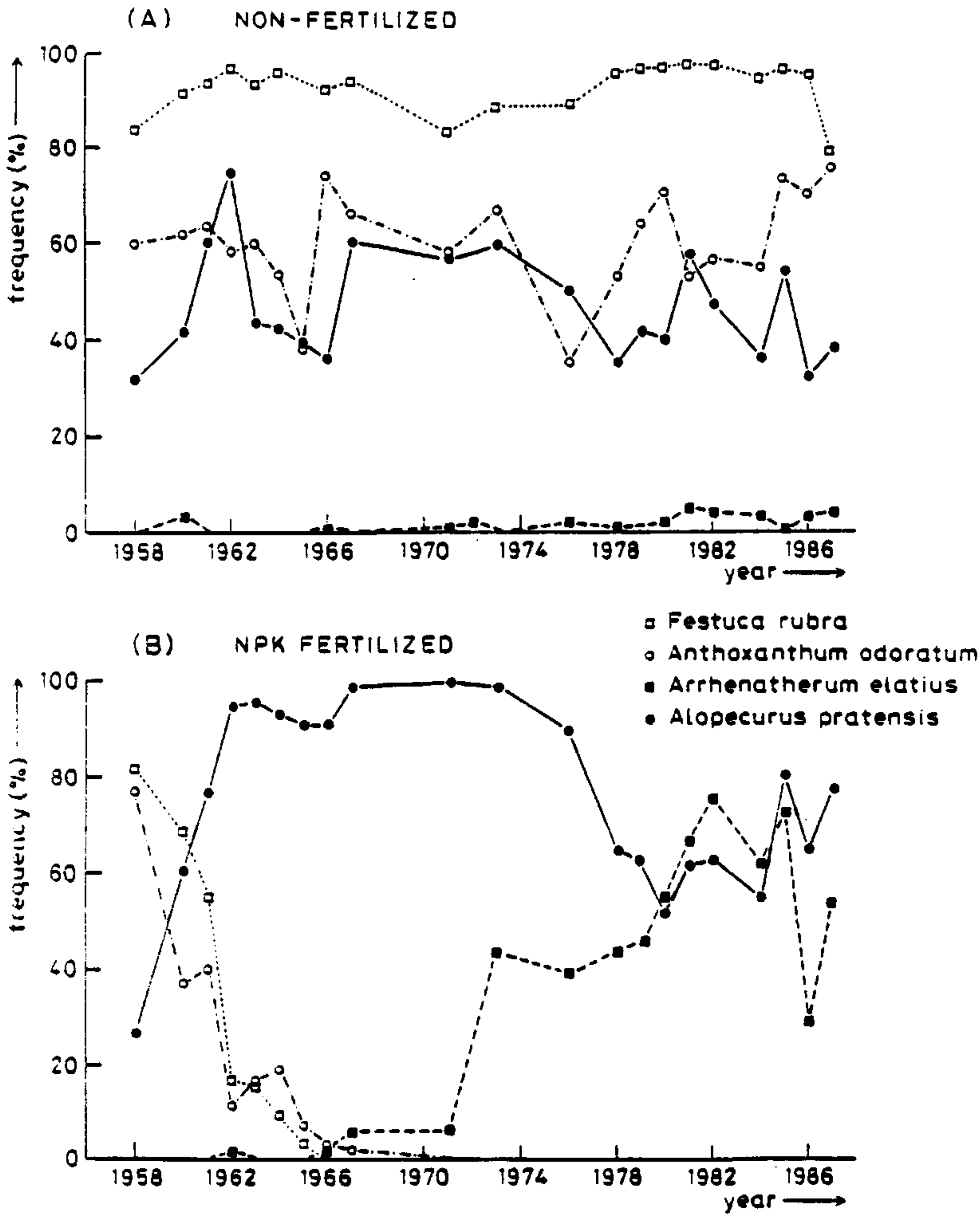

Figure 1. The frequency of four grass species in non-fertilized (a) and in fertilized (b) plots during 30 years in a hayfield on basin clay. Frequency has been measured as percentage of 2 x 50 samples with an area of 25 cm². (from Elberse et al., 1983)

2. Detailed description of the model

To describe the model in detail, it has been divided into 5 sections. Each section performs a defined task in the simulation of plant growth and consists of one or more so-called subroutines. The sequence of the paragraphs in this chapter is equal to the sequence in execution of these subroutines. The subroutines are executed by CALL statements from the main program (see Figure 2 and Appendix 2). The main program also contains the parameters and data, which have identical values for all species (non-specific) and it regulates the time conditions.

The model has been written in FORTRAN 77 and executed on a personal computer. The time step of integration (DELT) is one day and the rectangular integration method has been used.

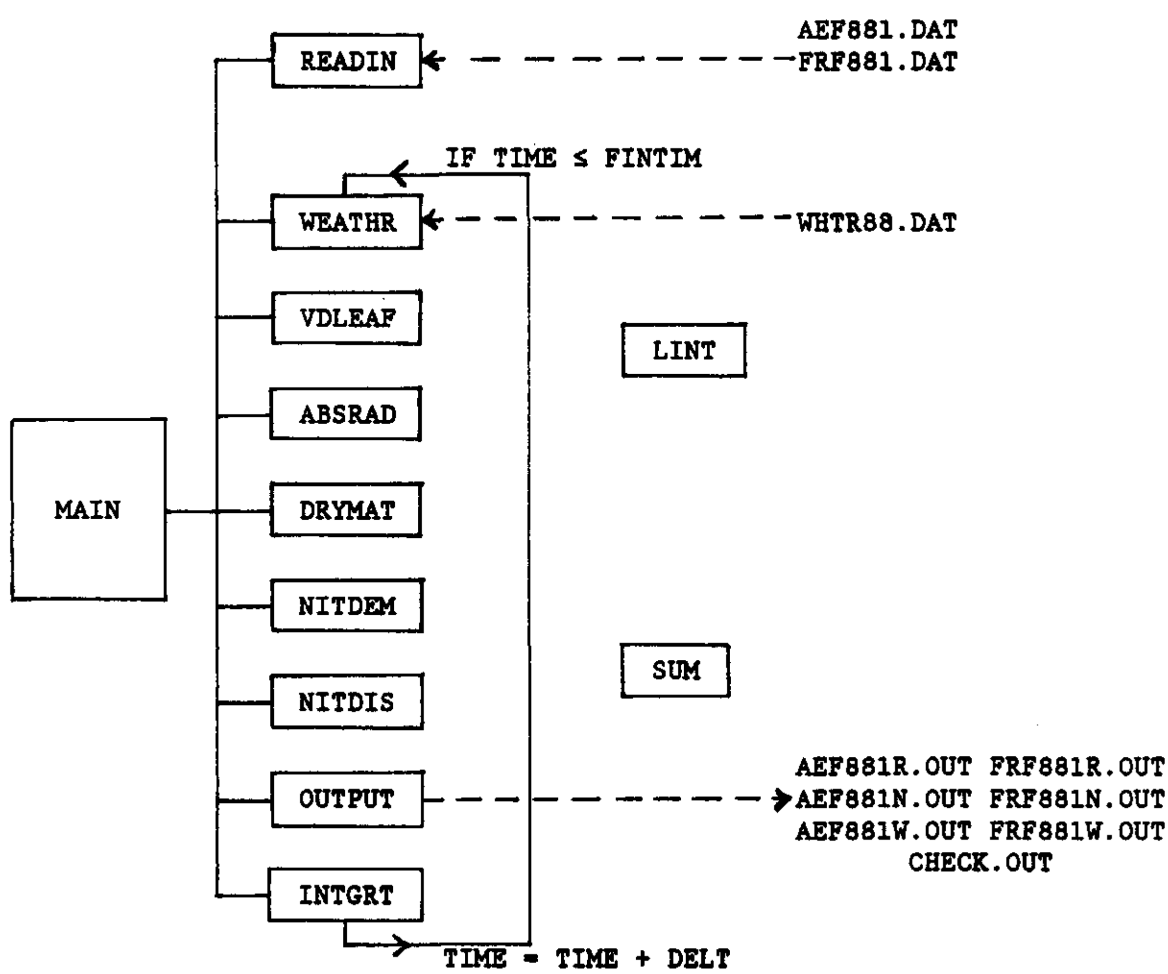

Figure 2 : Structure of the program COMPETITION with the main program, the subroutines, the functions (SUM & LINT), the input and output files.

Some of the calculations are performed by using functions.

- The function SUM sums a variable over all species.
- The function LINT carries out a linear interpolation of data.

2.1 Data input

The section "Data Input" concerns the input of initial data, which are needed to start the computations. These data are read from input files, which have the extension .DAT (see Appendix 4).

READIN

In the subroutine READIN the program is provided with information about the characteristics of the species. The characteristics of Arrhenatherum elatius and Festuca rubra, growing in the first period under fertilized conditions, are used as an example. The first period ran from the end of March until the first cut in June and contained 5 harvests.

The information has been divided in three categories :

1. Parameters ;
   they remain constant throughout an entire simulation run.
2. Tables ;
   a table contains the development of a variable in time.
3. Initial values ;
   initial values of state variables are read.

All parameters, tables and initial values have been derived from mono culture or from literature. When a mixed culture is simulated, the initial values are calculated by dividing the initial values, measured in mono culture, by the number of competing species.

READIN is executed only once per simulation run.

WEATHR

The subroutine WEATHR reads weather data, which have been derived from a station in Wageningen : minimum and maximum temperature per day and the daily total of global radiation. These data may be different from the really experienced values, since the Sinderhoeve is situated at a distance of 5 km from Wageningen. It has been assumed, that these (possible) differences are not essential to the dynamics of the species. Data on temperature have not yet been used in the model.

2.2 Dry matter

The section "Dry Matter" concerns the calculation of the dry matter production of each species and the distribution of dry matter over the various plant parts (see DRYMAT). The rate of dry matter production is partly determined by the amount of radiation, which has been absorbed by a species (see ABSRAD). This amount of absorbed radiation depends on the distribution of the leaf area index with the height of a species (see VDLEAF).

Dry weight and amount of dry matter are used as similar expressions. Whenever roots, leaves, stems or ears are mentioned, live organs are meant. Dead organs are indicated with the prefix "dead" in the text and an extra "D" in the abbreviations.

VDLEAF

The subroutine VDLEAF calculates the vertical distribution of the leaf area index of each species in a mixed culture. The vegetation is divided into horizontal layers by using the heights of the competing species. A diagram of a mixed culture with two species, differing in height, is drawn in Figure 3.

The top layer (L=1) contains only leaves of the highest species. The next layer (L=2) contains leaves of the highest and second-highest species. The two layers at the bottom (L=2,3) contain leaves of both species. The bottom layer is created by setting its upper boundary at half-height of the lowest species. When the two species have equal heights, the top layer is omitted and the number of layers equals the number of species.

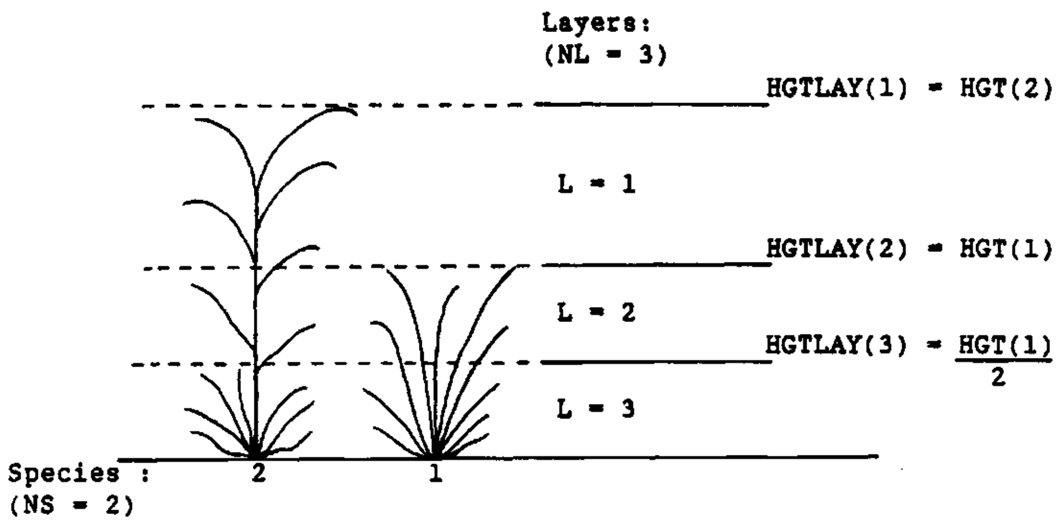

Figure 3 : A diagram of a mixed culture with two species, differing in height. Three horizontal layers are distinguished and their boundaries are determined by the heights of the species.

HGT	: Height of a species	(cm)
HGTLAY	: Height of a horizontal layer (upper boundary)	(cm)
NS	: Number of species	(-)
NL	: Number of layers	(-)

NL = NS + 1

To determine the boundaries of the layers and to calculate the leaf area index in each layer, two relations have been applied :

1. a relation between time and the height of a species.
2. a relation between height above ground surface and the leaf area index, beneath that height.

Both relations have been derived from mono culture by using a metal frame with 8 horizontal layers, created by cross-beams at fixed heights (Figure 4).

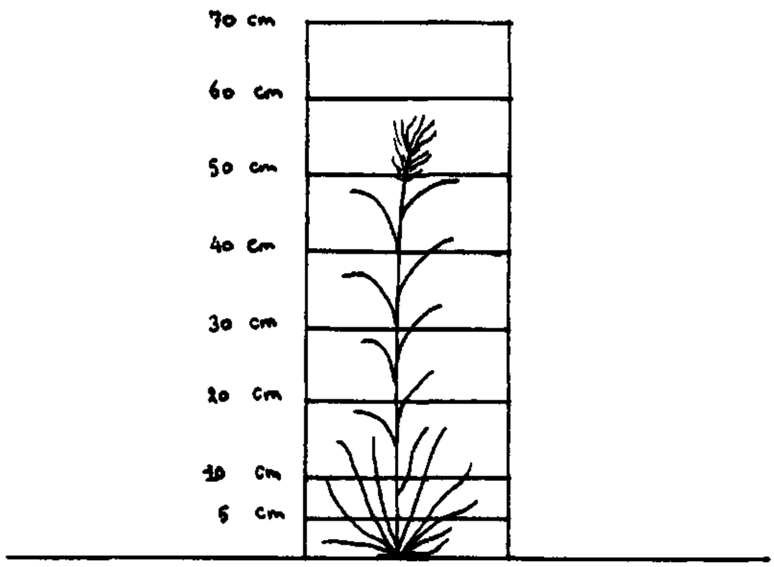

Figure 4 : The metal frame, which has been used in measuring the vertical distribution of the leaf area index of a species.

In the model the plant height equals the upper boundary of the highest layer of the metal frame, in which leaves of a species were present. For each day of the simulation period the heights of the species are calculated by linear interpolation of the harvest data (Figure 5). These heights determine the boundaries between the horizontal layers, used in the model.

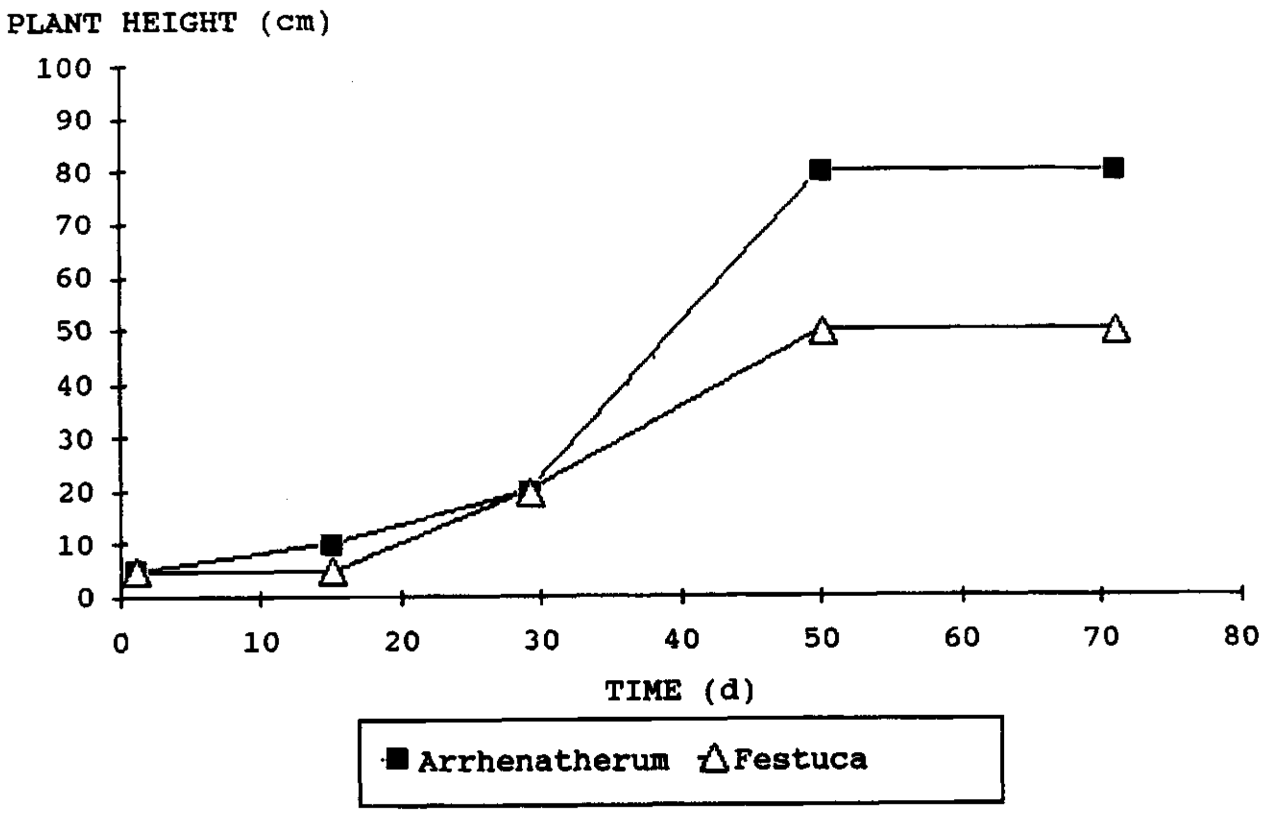

Figure 5 : The relation between time and plant height (cm), based on leaves, as measured with the metal frame. Time has been expressed in number of days, counted from the first harvest. Data were collected in 1988 at the following dates :
28-3, 11-4, 25-4, 16-5 and 6-6. Corresponding times : 1 , 15 , 29 , 50 and 71.

Data on leaf area were collected seperately in each layer of the metal frame to determine the vertical distribution. With these data the leaf area index beneath the upper boundary of each frame layer has been calculated. To find a useful relation between height above ground surface and the leaf area index, both variables have been expressed in a relative way :
the height has been made relative to the plant height, i.e. the upper boundary of the highest leaf layer, and
the leaf area index has been converted into its fraction of the total leaf area index of a species (Figure 6a and 6b).

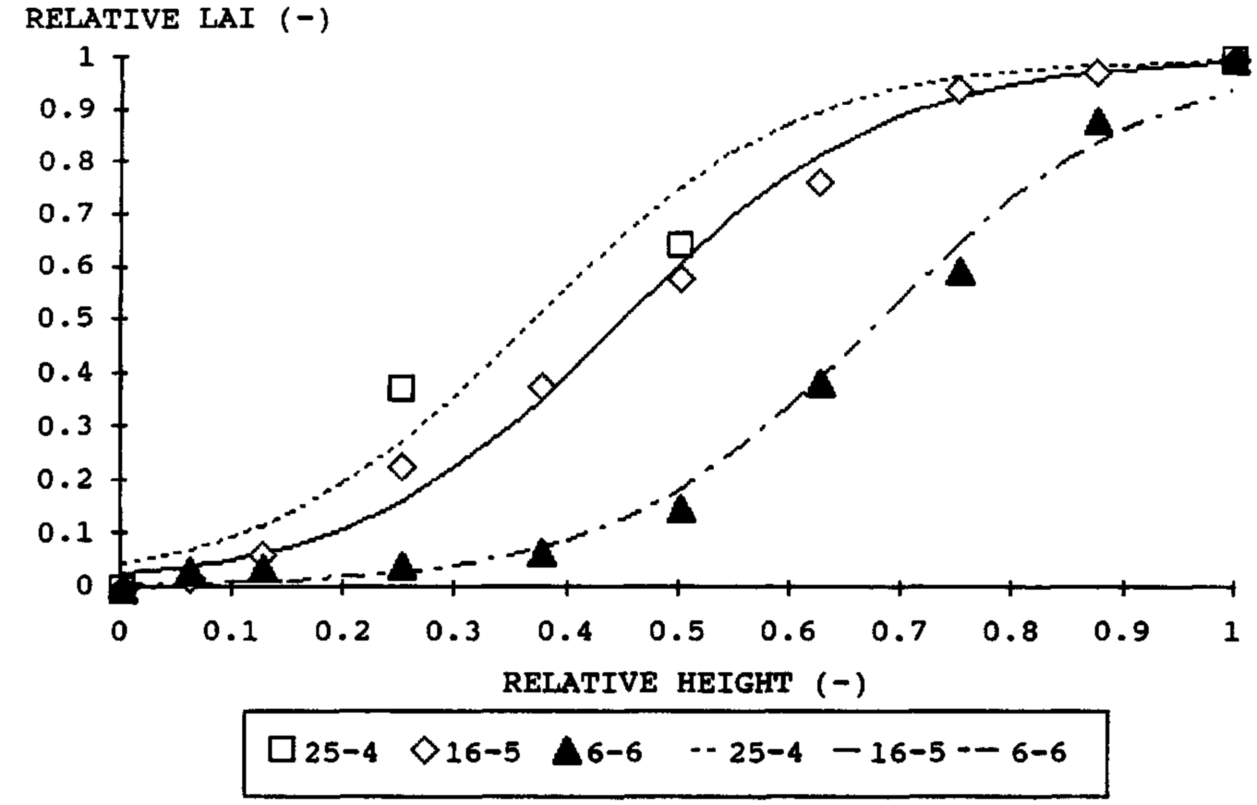

Figure 6a : The relation between the relative height and the relative leaf area index of Arrhenatherum elatius at three harvests. The drawn lines represent the fitted functions.

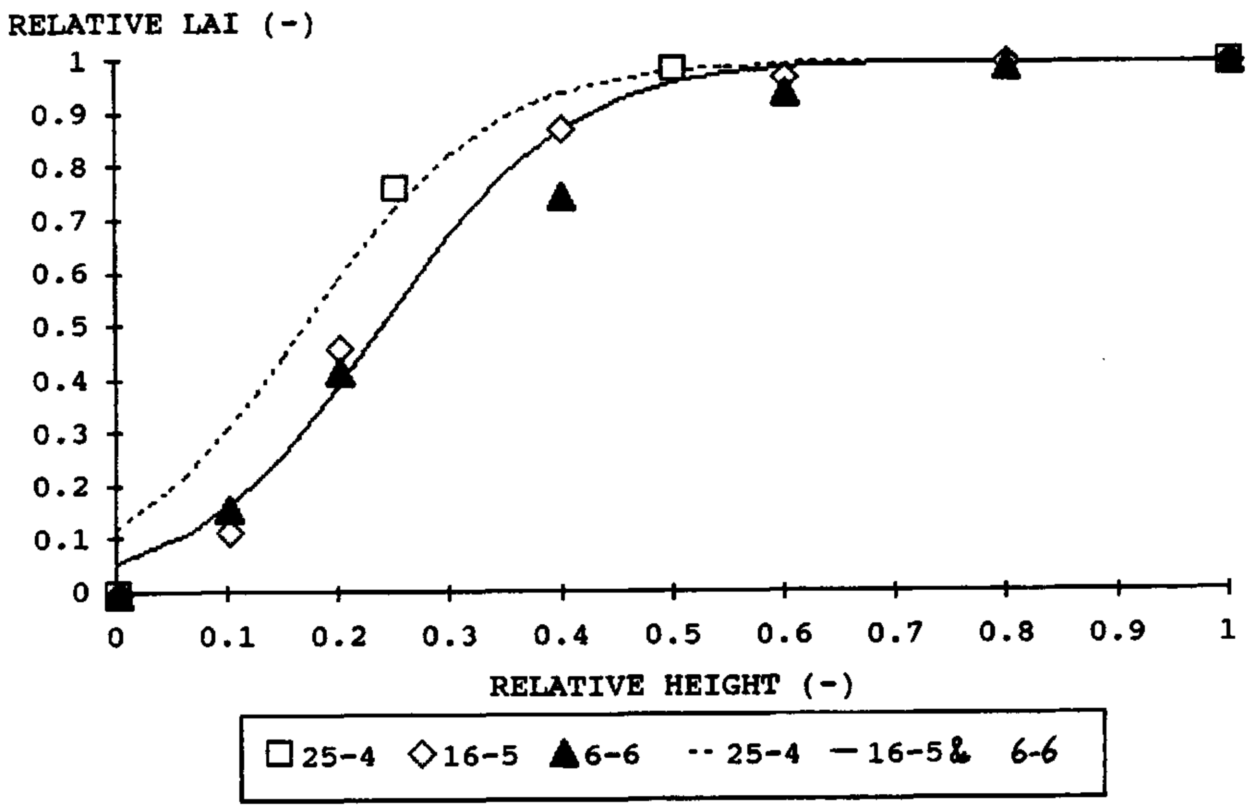

Figure 6b : Like Figure 6a, but data derived from Festuca rubra.

The number of data at each harvest depends on the number of horizontal frame layers, which were occupied by the leaves of a species. For instance, at the first harvest both species were only present in the bottom layer beneath 5 cm. The data from the first and second harvest are not plotted in Figure 6a & 6b, because they gave too little information about the vertical distribution of the leaf area index.

The relative leaf area index beneath a relative height is calculated by means of a function with the following formula :

$$\text{LAIREL(L)} = \frac{1}{1 + \text{EXP}(-\text{VDLK} * (\text{HGTREL(L)}-\text{VDLV}))} \qquad (1)$$

LAIREL(L)	: Leaf area index of a species beneath the upper boundary of layer L, relative to the total leaf area index (LAI) of a species	(-)
HGTREL(L)	: Height above ground surface, relative to the height of a species	(-)
VDLK,VDLV	: Parameters of the vertical distribution function	(-)
EXP	: Exponential function	

The used function has been derived from the logistic function by setting the numerator to 1, which refers to the maximum relative leaf area index.

The non-linear regression analysis of the statistical program GENSTAT has been used to estimate the two paramaters : VDLK and VDLV. The estimation procedure contained two parts and in each part one of the parameters was estimated. In order to determine VDLK the function was fitted to the data of harvest 4 and to the data of harvest 5, because they contain most of the data. The two estimations of the parameter VDLK, from harvest 4 and harvest 5, were used to calculate an average VDLK for each species, which is applied in the model as a constant. The average VDLK of Arrhenatherum equals 8.4, whereas that of Festuca equals 11.8. The VDLK, divided by 4, refers to the slope of the function in its inflection point. In order to determine VDLV the function was fitted again using the averaged VDLK, which had been found earlier. This time only VDLV was estimated in the regression analysis and this was done for the harvest 3, 4 and 5. The data of Festuca rubra at harvest 4 and 5 were pooled, because of the small differences in the vertical distribution of the leaf area index. According to the estimations at each harvest, the parameter VDLV varies in time (Figure 7).

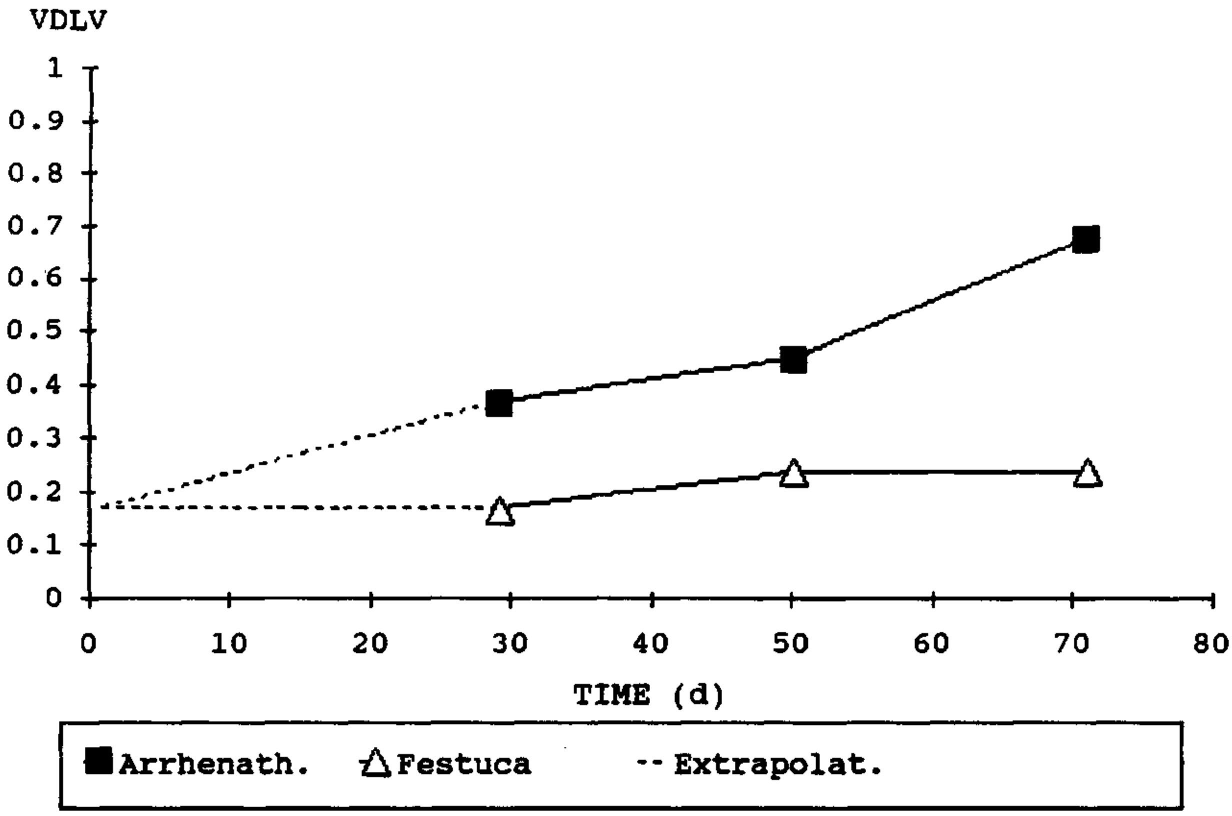

Figure 7 : The relation between time, expressed in days, and the VDLV of the vertical distribution function of the leaf area index.
For explanation, see text.

VDLV refers to the relative height, beneath which half of the total leaf area index is present. At harvest 1 the VDLV of both species are assumed to be equal to the VDLV of Festuca from harvest 3. Between harvest 1 and harvest 5 the VDLV of each day is found by linear interpolation.

In the model the leaf area index of each species in a layer is calculated by taking the difference between the leaf area index beneath the upper boundary of this layer and the leaf area index beneath the upper boundary of the next layer.

$$LAILAY(L) = LAI * (LAIREL(L) - LAIREL(L+1)) \qquad (2)$$

LAILAY(L) : Leaf area index of a species in layer L (-)
LAI : Leaf area index of a species (-)

The leaf area indices per layer are used to calculate the amount of radiation, absorbed by each species.

ABSRAD

The subroutine ABSRAD calculates the amount of radiation, which has been absorbed per species. The same set of equations can be applied for each horizontal layer. In a layer part of the incoming radiation is transmitted towards the next layer, whereas the other part is absorbed by the total biomass in this layer (Figure 8, Eqn. 3).

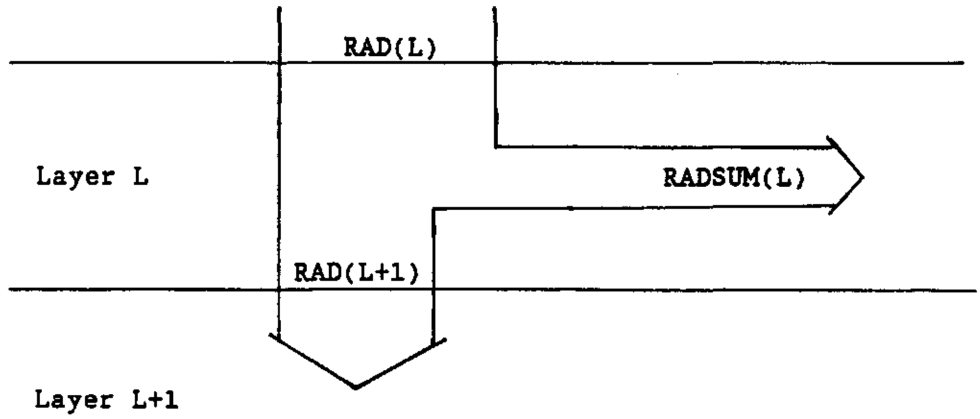

Figure 8 : A diagram of a horizontal layer with incoming, transmitted and absorbed radiation.

$$RADSUM(L) = RAD(L) - RAD(L+1) \qquad (3)$$

RAD(L) : Amount of radiation, entering layer L (J/cm².d)[NB]
RAD(L+1) : Amount of radiation, entering layer L+1 (J/cm².d)
RADSUM(L) : Amount of radiation, absorbed per layer, summed over all species (J/cm².d)

To calculate the amount of absorbed radiation in each layer (RADSUM) the following information has to be determined :

1. The amount of incoming radiation at the top layer (RAD(1)).
2. A relation between the amount of transmitted radiation and the biomass in a horizontal layer.

The amount of incoming radiation at the top layer is calculated by dividing the daily total of global radiation by two, because only half of it is photosynthetically active. Moreover 8 % (REFLCF) of this amount is reflected to the hemisphere by soil and vegetation (Eqn. 4 ; Spitters, 1988).

NB : In this report the expressions J/cm².d and g/m².d are used for J cm^{-2} d^{-1} and g m^{-2} d^{-1} respectively.

$$RAD(1) = RADGLB * 0.5 * (1 - REFLCF) \quad (4)$$

RADGLB : Amount of daily total global radiation ($J/cm^2.d$)
REFLCF : Reflection coefficient (-)

The amount of transmitted radiation is related to the incoming radiation and to the sum of the leaf area indices of all species in a layer, weighed by their extinction coefficients.

$$LAISUM(L) = \Sigma\ (LAILAY(S,L) * EXTCF(S)) \quad (5)$$
for S = 1 to NS

$$RAD(L+1) = RAD(L) * EXP(-LAISUM(L)) \quad (6)$$

EXTCF : Extinction coefficient (-)
LAILAY : Leaf area index of a species in a layer (-)
LAISUM : Product of leaf area index and extinction coefficient, per layer, summed over all species (-)

In the model an extinction coefficient of 0.6 is used for Arrhenatherum elatius, whereas an extinction coefficient of 0.5 is applied for Festuca rubra. Both extinction coefficients have been derived from literature, based on measurements in the field. The difference between the two is based on the observation, that the leaves of Festuca are more erect than those of Arrhenatherum (Verberne, 1987).

The amount of radiation, absorbed per layer, is distributed over the competing species according to their share in the extinction of the incoming radiation.

$$RADLAY(S,L) = RADSUM(L) * \frac{(LAILAY(S,L)*EXTCF(S))}{LAISUM(L)} \quad (7)$$

RADLAY : Amount of absorbed radiation per species and per layer ($J/cm^2.d$)

For each species the amount of radiation, which has been absorbed per layer, is summed over all layers, giving the amount of absorbed radiation per species (RADABS). This amount is used for calculating the net production of dry matter.

DRYMAT

In the subroutine DRYMAT the rates of production, allocation and loss of dry matter are calculated.

The daily net production of dry matter, which results from assimilation and respiration, is calculated by multiplying the amount of absorbed radiation with an efficiency coefficient. Spitters mentioned a maximum efficiency in the order of 3 g DM per MJ absorbed radiation for ruderal C3 species (Spitters, 1988). This value is used in the model for both species. The actual efficiency depends on the concentration of nitrogen in live leaves (Figure 9, Eqn. 8).

$$RDMP = RADABS * EDMP * REDN * 1.E+4 \qquad (8)$$

RDMP : Rate of dry matter production ($g/m^2.d$)
RADABS : Amount of absorbed radiation per species ($J/cm^2.d$)
EDMP : Efficiency of dry matter production (maximum) (g DM/J)
REDN : Factor of reduction on the dry matter production, caused by suboptimum nitrogen concentration (-)
1.E+4 : Conversion factor : cm^2 into m^2

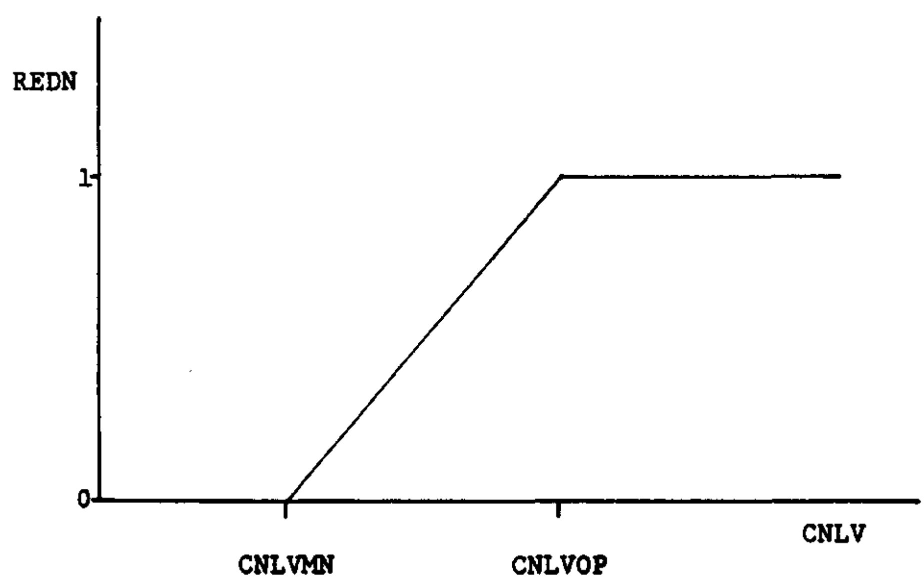

Figure 9 : The relation between the nitrogen concentration in live leaves and the reduction on the dry matter production, as used in the model.

CNLV : Concentration of nitrogen in leaves (g N/g DM)
CNLVMN : Minimum nitrogen concentration in leaves (g N/g DM) (a constant, below which the efficiency equals zero)
CNLVOP : Optimum nitrogen concentration in leaves (g N/g DM) (a variable, above which the efficiency is at its maximum)

The various nitrogen concentrations in leaves refer to average concentrations over all live leaves of a species. It has been assumed, that the optimum nitrogen concentration equals a constant fraction (0.65) of the maximum nitrogen concentration (Spitters, 1988). As time proceeds, the maximum nitrogen concentration will decrease (see NITDEM) and therefore a lower nitrogen concentration will be sufficient in this model to keep or obtain the maximum efficiency. This can be explained as follows: With increasing leaf area index, the amount of absorbed radiation, measured per unit of leaf area, per second and averaged over all live leaves, will decrease. Measurements, based on single leaves, show that the optimum nitrogen concentration is positively correlated with the amount of absorbed radiation per unit of leaf area, per second (Hirose and Werger, 1987). When a plant develops a higher leaf area index, it will be satisfied with a lower nitrogen concentration in producing dry matter at maximum efficiency. This is only valid, if the plant distributes its nitrogen in an economic way, which means that leaves, which absorb more radiation, will contain more nitrogen and vice versa. A minimum nitrogen concentration of 0.008 g N/g DM is used (Spitters, 1988).

The daily production of dry matter is distributed over all plant parts by using allocation factors. The product of the rate of dry matter production and an allocation factor gives the rate of dry matter allocation towards a plant organ.

$$RDMART = FADMRT * RDMP \quad (9)$$

for each plant organ

RDMART : Rate of dry matter allocation to roots $(g/m^2.d)$
FADMRT : Factor of allocation of dry matter to roots (-)

The sum of all allocation factors equals one. The dry matter allocation factors have not yet been determined from the experimental data. Test values are used instead (see Appendix 4).

In the model only roots and leaves die off during the simulation period. Dead roots and leaves do not contribute to the growth processes any more, as if they have been shed. Their death is simulated by a dry matter loss from live biomass and this is calculated by multiplying their dry weights with a constant relative death rate.

$$RDMLRT = RDRRT * WRT \qquad (10)$$
$$RDMLLV = RDRLV * WLV \qquad (11)$$

RDMLRT	: Rate of dry matter loss through death of roots	($g/m^2.d$)
RDRRT	: Relative death rate of roots	(d-1)
WRT	: Dry weight of roots	(g/m^2)
RDMLLV	: Rate of dry matter loss through death of leaves	($g/m^2.d$)
RDRLV	: Relative death rate of leaves	(d-1)
WLV	: Dry weight of leaves	(g/m^2)

The relative death rates of roots and leaves are assumed to be equal for both species at a constant value of 0.01 and 0.015 respectively.

The result of allocation and loss gives the net change of dry matter per day for each organ. These net flows are integrated in time to give the new live biomass of each organ (see INTGRT).

2.3 Nitrogen

This section concerns the availability of nitrogen in the soil and the distribution of nitrogen over the competing species by calculating their uptake rates (NITDIS). It also determines the loss of nitrogen from live biomass and the distribution of nitrogen over all live organs.

NITDEM

The subroutine NITDEM determines the demand for nitrogen of each species. In calculating the nitrogen demand experimental data, derived from literature, have been used. These data show that the nitrogen concentrations in live biomass reach maximum values even if there is still nitrogen available in the soil (Seligman et al., 1975 ; Penning de Vries et al., 1978). The amount of nitrogen, which has to be taken up to reach these maximum concentrations, is called the nitrogen demand of a species. It is calculated as the difference between the maximum and the actual amount of nitrogen, taking the nitrogen loss into account.

$$RNDLB = (ANLBMX - ANLB)/DELT + RNLRT + RNLLV \qquad (12)$$

RNDLB	: Rate of nitrogen demand of live biomass	($g/m^2.d$)
ANLBMX	: Amount of nitrogen in live biomass (maximum)	(g/m^2)
ANLB	: Amount of nitrogen in live biomass	(g/m^2)
RNLRT	: Rate of nitrogen loss through death of roots	($g/m^2.d$)
RNLLV	: Rate of nitrogen loss through death of leaves	($g/m^2.d$)
DELT	: Time step of integration	(d)

The maximum amount equals the sum of the products of the dry weights of the live organs with their maximum nitrogen concentrations. The maximum concentrations decrease in time, because the proportion of structural components with lower nitrogen concentrations will increase in the biomass, as the plant matures (Seligman et al., 1975). A linear relation between time and the maximum nitrogen concentrations has been assumed (Figure 10 ; see also Spitters, 1988).

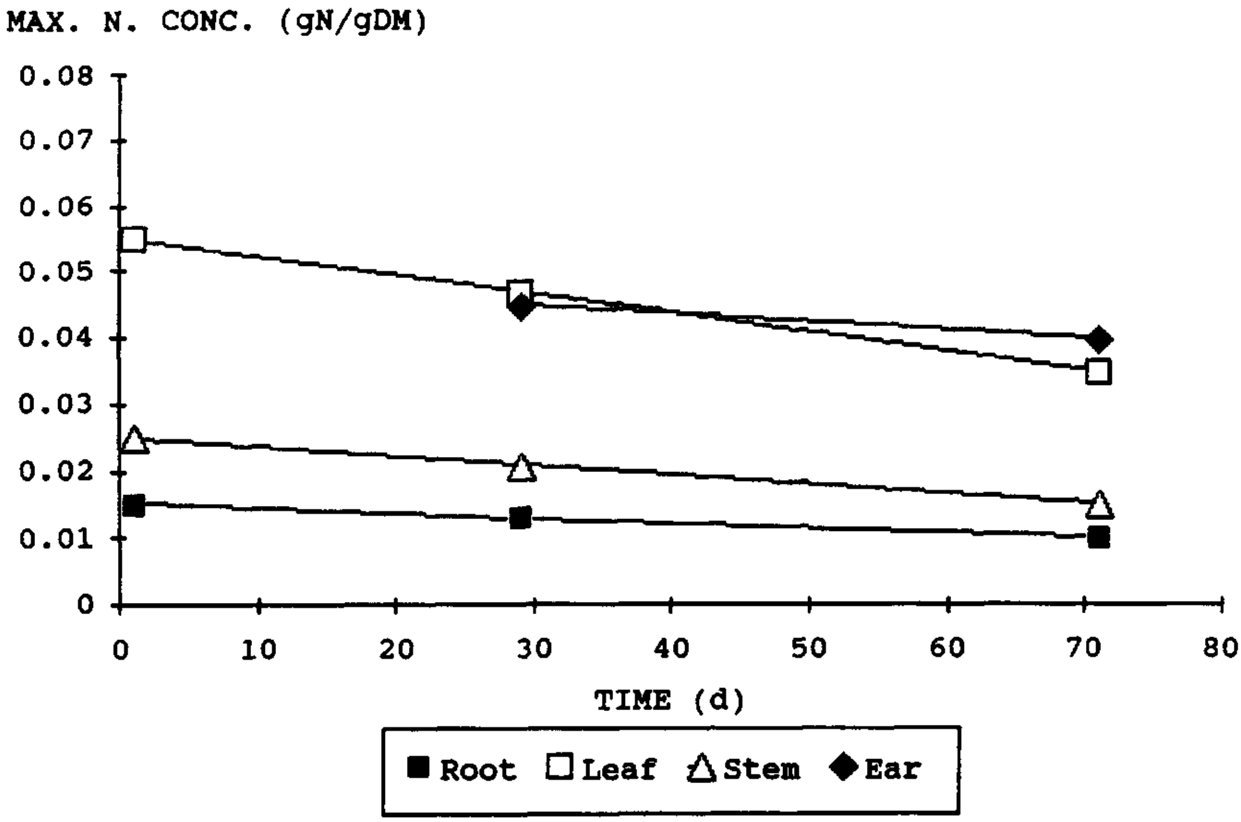

Figure 10 : The relation between time and the maximum nitrogen concentrations (g N/g DM), as used in the model, for both species.

The nitrogen loss from the plant results from roots and leaves, which are dead but still contain a certain amount of nitrogen.

RNLRT = RDMLRT * CNDRT (13)
RNLLV = RDMLLV * CNDLV (14)

CNDRT : Concentration of nitrogen in dead roots (g N/g DM)
CNDLV : Concentration of nitrogen in dead leaves (g N/g DM)

The nitrogen concentrations in dead roots and leaves are assumed to be equal for both species at a constant value of 0.005 gN/gDM.

NITDIS

The subroutine NITDIS calculates the supply rate of nitrogen in the soil and the nitrogen uptake rates of each species. It also determines the net flows of nitrogen as a result of uptake and loss rates and the allocation factors for nitrogen towards the various plant organs.

The rate of nitrogen supply in the soil is calculated by dividing the amount of available nitrogen by the time step of integration.

$$RNS = ANSL/DELT \qquad (15)$$

RNS : Rate of nitrogen supply in the soil ($g/m^2.d$)
ANSL : Amount of available nitrogen in the soil (g/m^2)

The nitrogen supply rate is distributed over the competing species according to their relative root length indices under the condition that the nitrogen uptake of a species does not exceed its nitrogen demand. It has been assumed that all species have equal absorption characteristics per unit of root length.

RNS = ANSL/DELT (initial value)
RNU = 0 (initial value)

RNU = RNU + RNS * RLI/RLISUM (16)
IF RNU > RNDLB => RNU = RNDLB (17)
RNS = (ANSL/DELT) - SUM(RNU,NS) (18)

RNU : Rate of nitrogen uptake per species ($g/m^2.d$)
RLI : Root length index of a species (m/m^2)
RLISUM : The sum of the root length indices of all species with RNU < RNDLB
SUM : A function, which sums RNU over all species

The distribution calculations (16),(17) & (18) will be executed again, if there is still some nitrogen available (Eqn. (18) : if ANSL/DELT > SUM(RNU,NS)) and if at least one of the species has not yet satisfied its demand (if RNU < RNDLB). This will continue until all available nitrogen has been taken up (Eqn. (18) : if ANSL/DELT = SUM(RNU,NS)) or each species has been able to satisfy its demand (if RNU = RNDLB, for all species).

The net flow of nitrogen into live biomass equals the difference between the rate of nitrogen uptake and the nitrogen loss rates (see NITDEM).

$$NFNLB = RNU - RNLRT - RNLLV \qquad (19)$$

NFNLB : Net flow of nitrogen into live biomass ($g/m^2.d$)

The distribution of nitrogen over the various plant organs is calculated by multiplying the actual amount of nitrogen in live biomass with the nitrogen allocation factors of each organ (see INTGRT). In simulating this distribution two assumptions have been made :

- Nitrogen can easily be withdrawn from one place to be allotted elsewhere.
- The actual nitrogen allocation factor equals the relative maximum amount of nitrogen in each organ.

This means that the nitrogen distribution is simulated by the distribution of dry matter over the organs, weighed by their maximum nitrogen concentrations.

$$FANRT = ANRTMX \; / \; ANLBMX \qquad (20)$$

for each plant organ

FANRT	: Factor of allocation of nitrogen to roots	(-)
ANRTMX	: Amount of nitrogen in roots (maximum)	(g/m^2)
ANLBMX	: Amount of nitrogen in live biomass (maximum)	(g/m^2)

2.4 Data output

The section "Data Output" concerns writing the major results of the computations in output files with the extension .OUT (see Appendix 5 & 6) .

OUTPUT

In the subroutine OUTPUT three output files are created for each species :

- ......R.OUT with results on height, leaf area index and absorbed radiation.
- ......N.OUT with results on root length index, the availability, uptake and distribution of nitrogen and the nitrogen concentrations.
- ......W.OUT with results on the dry matter distribution.

The file CHECK.OUT contains the check variables of all species, which have been determined to check the four main distribution calculations.

1. CHKLAI checks the vertical distribution of the leaf area index of each species (in VDLEAF).
2. CHKRAD checks the distribution of the amount of radiation, which has been absorbed by the whole vegetation (in ABSRAD).
3. CHKWTT checks the distribution of dry matter among the various plant parts of each species, including the dead biomass (in INTGRT).
4. CHKNIT checks the distribution of nitrogen among soil, live and dead biomass (in INTGRT).

The check variables are calculated as the difference between the initial amount before distribution and the sum of the parts after distribution, expressed as a percentage. They all should be equal to zero and if so, than the distribution calculations in the model have been performed in a consistent way.

2.5 Integration

This section concerns integrating all state variables in time and it calculates for each species the root length index, the leaf area index and the nitrogen concentrations in all live organs.

The initial dry weights of the various plant parts have been derived from the first harvest at the 28th of March. It was not possible to distinguish between live and dead roots and it is assumed that only half of the measured root dry weight was alive. The initial amounts of nitrogen have not been yet determined from the data of the experiment. They have been calculated by using equal nitrogen concentrations for both species at the first day of the simulation : 0.10 g N/g DM for the roots,
0.25 g N/g DM for the leaves and
0.15 g N/g DM for the stems.

INTGRT

The subroutine INTGRT integrates the biomass of each plant part in time. The new biomass equals the old biomass plus the net flow times DELT (time step of integration).

$$WRT = WRT + NFDMRT * DELT \qquad (21)$$

for each plant part

NFDMRT : Net flow of dry matter into roots (g/m².d)

The root length index is calculated by multiplying the dry weight of live roots with the specific root length. Part of the live roots does contribute to the root length index, because it is present as a stump.

$$RLI = WRT * (1 - FRTN) * SRL \qquad (22)$$

FRTN : Fraction of the root biomass, which is present as a stump (-)
SRL : Specific root length (m/g)

The specific root lenghts have been derived from pot experiments in 1987 (personal communication, Elberse) and they amount to 124 m/g for Arrhenatherum and 293 m/g for Festuca. The stump part (FRTN) equals 0.26 for both species and has been derived from the mono culture data at the Sinderhoeve.

The leaf area index is calculated by multiplying the dry weight of live leaves with a specific leaf area, which has been derived from the experimental data, measured in mono culture (Figure 11).

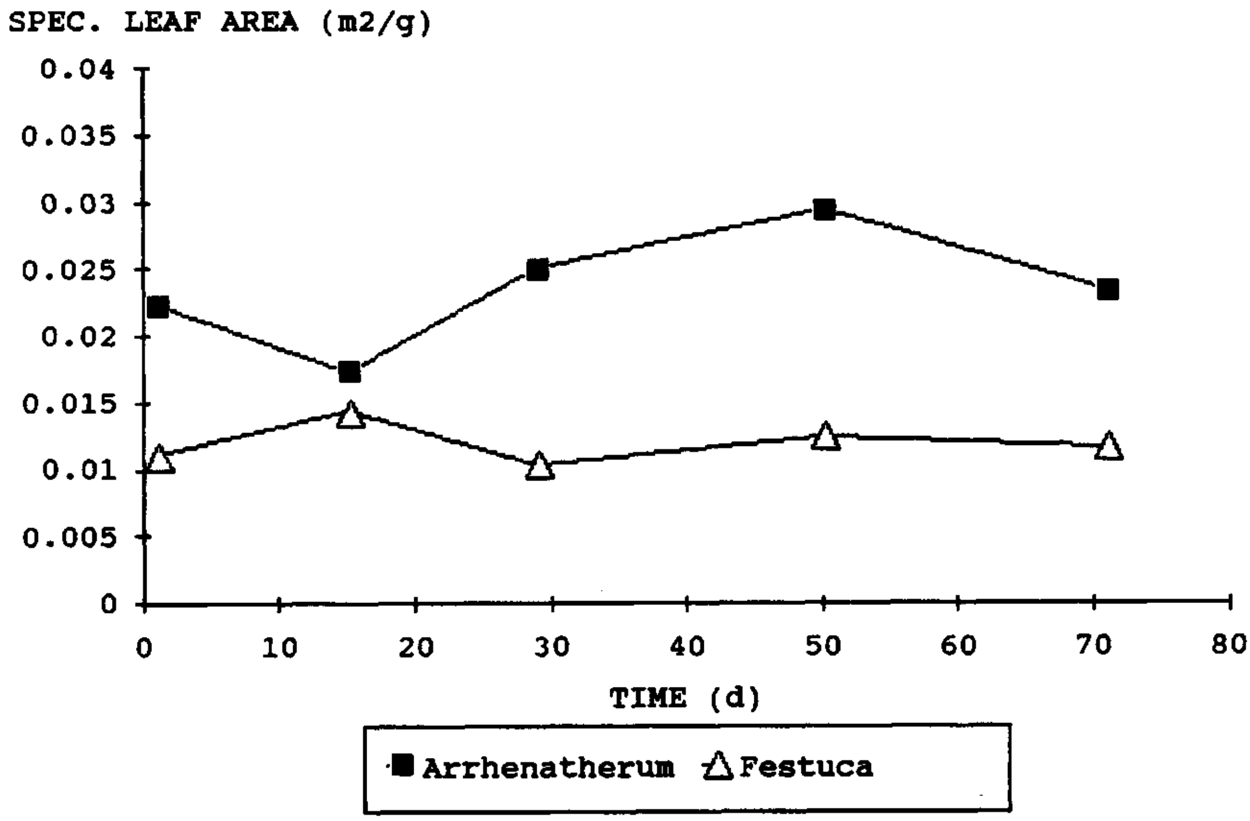

Figure 11 : The relation between time and the specific leaf area (m^2/g), as used in the model.

The new amount of nitrogen in live biomass is calculated by integrating the net flow of nitrogen into live biomass in time.

ANLB = ANLB + NFNLB * DELT (23)

ANLB : Amount of nitrogen in live biomass (g/m^2)

After integration, the amount of nitrogen in live biomass is distributed over the various plant organs, by using the nitrogen allocation factors (see NITDIS).

ANRT = FANRT * ANLB (24)
for each plant organ

ANRT : Amount of nitrogen in roots (g/m^2)

Nitrogen concentrations are calculated by dividing the amount of nitrogen by the dry weight of each live plant organ.

$$CNRT = ANRT / WRT \qquad (25)$$

for each plant organ

CNRT : Concentration of nitrogen in roots (g N/g DM)

The amount of available nitrogen in the soil is depleted by the uptake of nitrogen through each species and it is replenished through mineralisation and fertilisation. The nitrogen supply by mineralisation is assumed to be constant for the whole simulation period at a rate of 0.05 $g/m^2.d$. The nitrogen supply through fertilisation depends on the application date and on the amount of nitrogen gift, multiplied with a so-called recovery factor. In this model the species are able to take up the fertilizer nitrogen one day after the application date. Not all of the initially applied fertilizer nitrogen is available during the simulation period for the species. Part of it may leach out or become immobilized. The available part is calculated by multipying the nitrogen gift with the recovery factor. At the 8th of April an amount of 10 g nitrogen per m^2 has been applied. The recovery factor (0.55) has been derived from literature (Verberne, 1987). The new amount of available nitrogen in the soil is found by integrating the rates of uptake, mineralisation and fertilisation in time.

$$ANSL = ANSL + (RNSM + RNSF - SUM(RNU,NS))*DELT \qquad (26)$$

RNSM : Rate of nitrogen supply by mineralisation ($g/m^2.d$)
RNSF : Rate of nitrogen supply by fertilisation ($g/m^2.d$)

If time has not yet reached the end of the simulation period (FINTIM), the program begins computing again at the subroutine WEATHR and the new values of the state variables are the starting points on the next day.

3. Model behaviour

3.1 Computations check

All the check variables are approximately equal to zero (see CHECK.OUT, Appendix 6). The deviations from zero are caused by rounding effects of the programming language and they range from ±0.00005 % to ±0.000001 % . These small faults are negligible and the program carries out the main distribution calculations in a consistent way.

3.2 Simulation results

The model has been used to simulate the development of Arrhenatherum elatius and Festuca rubra, both in mono culture and in a mixed stand. The output files are given in Appendix 5 (mono cultures) and Appendix 6 (mixed culture). In the figures 12a & 12b and 13a & 13b the development of the leaf area index and the total biomass of the two species have been plotted. The experimental data from the mono cultures are given as references, but a validation of the model is not yet possible, because the parameterisation has not been completed. Corresponding data from the mixed stand of Arrhenatherum and Festuca have not been measured at the Sinderhoeve.

Under fertilized conditions the model, when executed with the species characteristics as described in chapter 2, favors Arrhenatherum with respect to Festuca in the production of dry matter in a mixed culture. This can be shown by calculating for each species the quotient between the total biomass in the mixed culture and the total biomass in the mono culture : WTOT(AE) in mixed / WTOT(AE) in mono. This quotient is for Arrhenatherum at most days more than 0.5 and at the same time for Festuca less than 0.5 (see Figure 12b & 13b). At the end of the simulation period (TIME = 71) the quotient of the total biomass equals 0.68 for Arrhenatherum and 0.33 for Festuca. This means that in the mixed stand the presence of Festuca results in a higher production of dry matter per individual Arrhenatherum, when compared with the mono culture, whereas the presence of Arrhenatherum has the opposite effect on Festuca[NB]. The simulated development the leaf area index is in agreement with this conclusion (see Figure 12a & 13a).

NB : Each species has been sown in a density of 1500 plant/m² in mono culture and 750 plant/m² in the mixed culture. Total sowing density is equal in both stands.

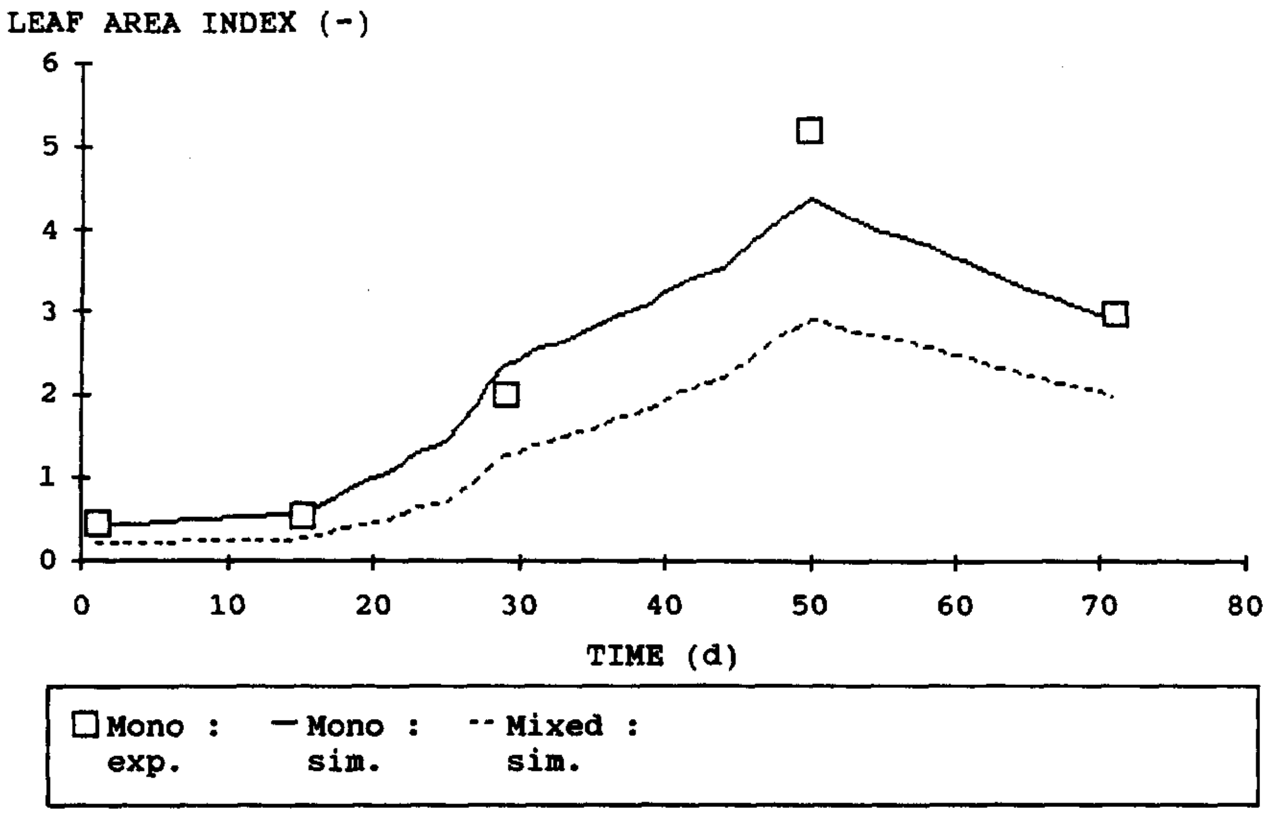

Figure 12a : The development of the leaf area index of Arrhenatherum in time, from the 28th of March (TIME=1) until the 6th of June (TIME=71). The symbols are data, measured in the mono culture (Mono : exp.). The solid line is the simulated development in mono culture (Mono : sim.) and the dashed line is the simulated development in a mixed culture with Festuca (Mixed : sim.).

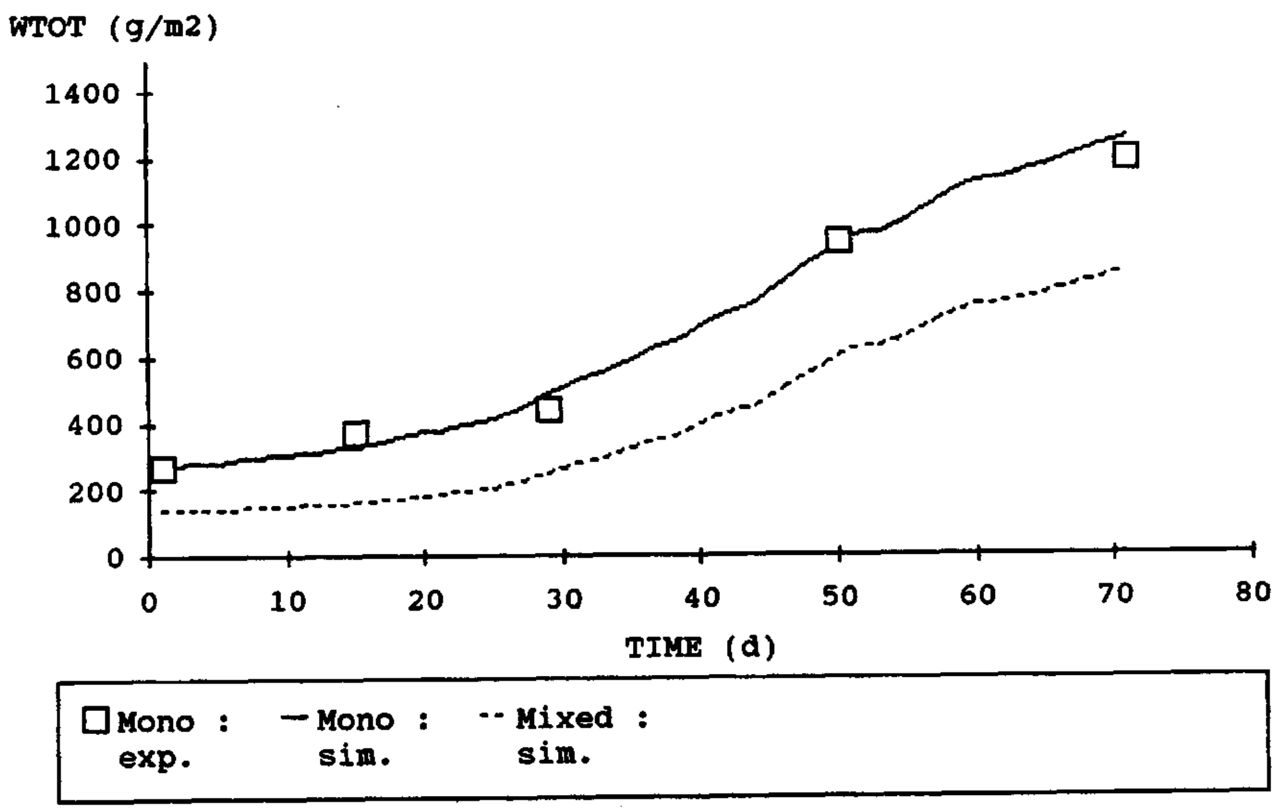

Figure 12b : The development of the total biomass (WTOT in g DM/m^2) of Arrhenatherum in time. For explanation of the legenda, see Figure 12a.

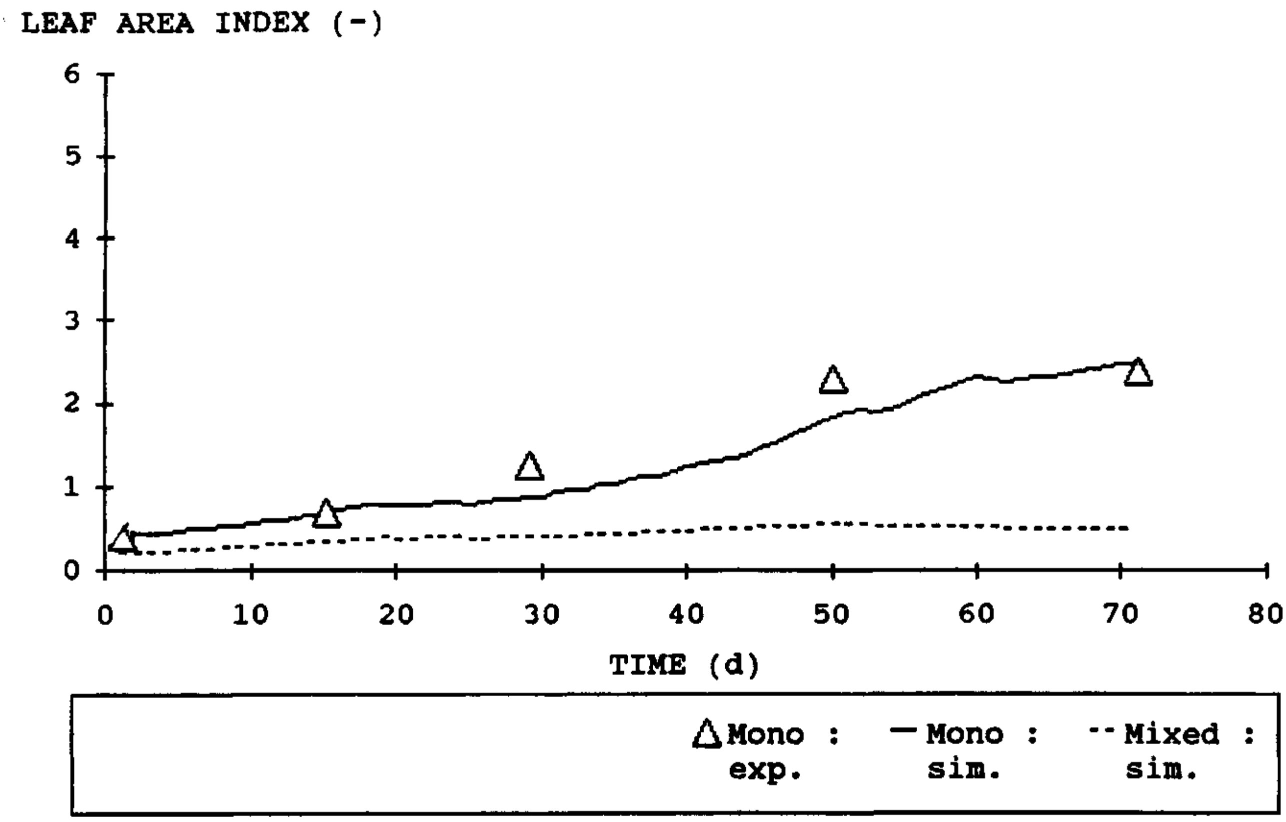

Figure 13a : Like Figure 12a, but the results apply to Festuca.

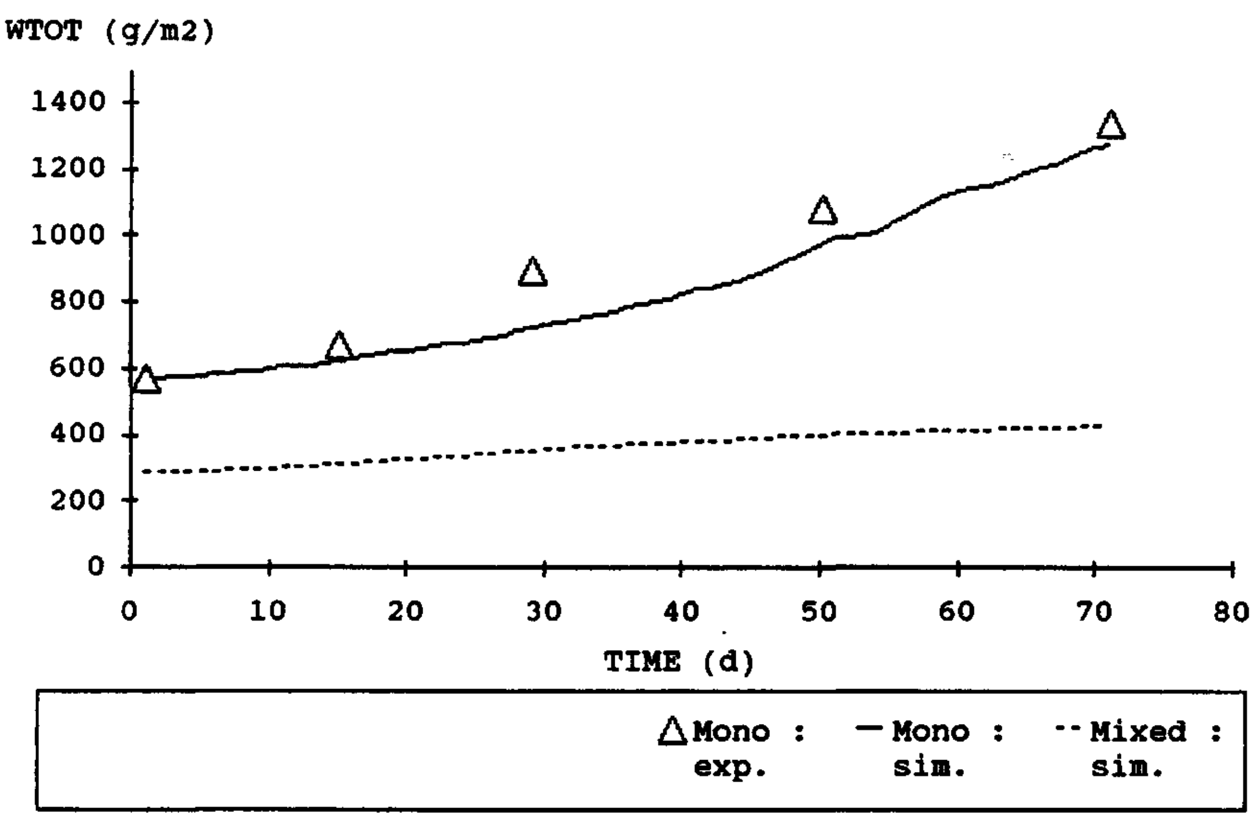

Figure 13b : Like Figure 12b, but the results apply for Festuca.

3.3 Sensitivity analysis

A sensitivity analysis has been performed to determine the effect of the input data on the biomass dynamics of Arrhenatherum elatius and Festuca rubra in a simulated mixed stand. The values of the input data have been changed one at the time and the following results have been compared :

-The increase in biomass[NB] (in g DM/m^2) of Arrhenatherum and Festuca during the simulation (Eqn. 27, 28).

$$\text{Increase(AE)} = \text{WLB(AE,TIME=71)} - \text{WLB(AE,TIME=1)} \quad (27)$$
$$\text{Increase(FR)} = \text{WLB(FR,TIME=71)} - \text{WLB(FR,TIME=1)} \quad (28)$$

-The biomass increase is also given in its percentage of the total biomass increase (Eqn 29, 30).

$$\text{AE} : \frac{\text{Increase(AE)}}{\text{Increase(AE)} + \text{Increase(FR)}} * 100\% \quad (29)$$

$$\text{FR} : \frac{\text{Increase(FR)}}{\text{Increase(AE)} + \text{Increase(FR)}} * 100\% \quad (30)$$

-The ratio between the biomass increase of Arrhenatherum with respect to that of Festuca (Eqn 31).

$$\text{Ratio (AE-FR)} = \frac{\text{Increase(AE)}}{\text{Increase(FR)}} \quad (31)$$

When the model is executed, using the input data as described in chapter 2, the live biomass in the mixed culture increases with 647 g DM/m^2, of which 94 % comes from Arrhenatherum and 6 % from Festuca. The dry matter increase of Arrhenatherum is 16.4 times higher than that of Festuca (see AEF881W.OUT & FRF881W.OUT, Appendix 6). These results are used as reference in the sensitivity analysis. The increase ratio, based on the mono culture simulations, equals 1.8, which means that even if there is no competition between the two species, the increase in live biomass of Arrhenatherum still exceeds that of Festuca during the simulation period. Under fertilized conditions Arrhenatherum increases with 64 % and Festuca with 36 % of the total increase in mono cultures.

NB : In this context biomass refers to live dry weight and an increase results from both production and loss of dry matter.

The input data have been subdivided into three clusters, because each cluster has been treated differently in the sensitivity analysis. These three clusters are :

1. Resource availability, which is equal for both species (daily total of global radiation or amount of nitrogen gift, etc.).
2. Species characteristics, in which Arrhenatherum and Festuca differ (height development or specific root length, etc.).
3. Species characteristics, which are assumed to be identical for both species (efficiency of dry matter production or relative death rates, etc.).

3.3.1 Resource availability

In the model two resources have been distinguished : radiation and nitrogen. The production of Festuca is only limited by the absorption of radiation, because Festuca never reaches a suboptimum nitrogen concentration (at most times, the REDN equals 1.0 ; see FRF881N.OUT, Appendix 6). On the other hand the production of Arrhenatherum is limited by the uptake of nitrogen (see REDN in AEF881N.OUT, Appendix 6), but it is not clear from the reference simulation, whether this species is also limited by radiation. The effect of the availability of the various resources has been studied by raising or lowering the availability with 10 % (see Table 1).

Setting the date of the fertilisation 5 days earlier (NGDATE = 7.) or 5 days later (NGDATE = 17.) has the greatest effect on the increase ratio. When the fertilizer nitrogen becomes available at a later point of time, Festuca increases more (+ 9 g/m^2), whereas Arrhenatherum increases less (- 21 g/m^2), as compared with the reference simulation. An earlier date of the fertilisation has the opposite effect on both species.

A ± 10 % change in the availability of nitrogen affects the biomass increase of Arrhenatherum, but has almost no effect on the biomass increase of Festuca (see NRECOV/RNSM, NRECOV and RNSM). On the other hand both species are limited by the availability of global radiation, but the change in the biomass increase of Festuca is relatively larger than that of Arrhenatherum (see PPA). Regarding the ratio between the biomass increase of Arrhenatherum with respect to that of Festuca, Arrhenatherum benefits from a higher nitrogen availability or a lower availability of the global radiation, whereas Festuca is favored by a lower nitrogen availability or a higher availability of the global radiation.

Table 1 : The effect of a 10 % change in the amounts of available radiation and nitrogen on the biomass dynamics of Arrhenatherum elatius (AE) and Festuca rubra (FR). The effects are listed in order of magnitude.

Input data	Old value	Change	New value	Increase in live biomass (g DM/m²) AE	FR	Increase ratio AE/FR
		reference :		610 (94%)	37 (6%)	16.4
NGDATE	12.	+5 d.	17.	589 (93%)	46 (7%)	12.8
		-5 d.	7.	620 (95%)	33 (5%)	18.7
NRECOV/		+10 %		657 (95%)	36 (5%)	18.3
RNSM		-10 %		556 (93%)	39 (7%)	14.1
PPA	0.50	+10 %	0.55	638 (93%)	44 (7%)	14.4
		-10 %	0.45	563 (95%)	31 (5%)	18.2
NRECOV	0.55	+10 %	0.605	641 (95%)	36 (5%)	17.7
		-10 %	0.495	576 (94%)	39 (6%)	14.9
RNSM	0.05	+10 %	0.055	627 (94%)	37 (6%)	17.2
		-10 %	0.045	593 (94%)	38 (6%)	14.9

NRECOV/ RNSM : Both parameters have been changed simultaneously with values of 0.605/0.055 (+10%) and 0.495/0.045 (-10%).

PPA : Part of the global radiation, which is photosynthetically active.

3.3.2 Different characteristics

The differences in the characteristics of Arrhenatherum and Festuca are responsible for the increase ratio of 16.4 in the reference simulation. The effect of these differences on the biomass increase has been examined by eliminating each difference one at the time. The original values of a characteristic have been changed into the same value for both species, which is set equal to the average of the original values.

The biomass dynamics are the most sensitive to the difference in the specific leaf area (see Table 2). When the two species do not differ in this characteristic, the increases in the biomass of Arrhenatherum and Festuca are almost equal, in spite of the differences in height or extinction coefficient, etc., which are favorable for Arrhenatherum (see SLA). The increase percentages change from 94- 6 % to 53-47 % and the increase ratio becomes 1.1.

Table 2 : The effect of eliminating the differences in the characteristics of Arrhenatherum elatius (AE) and Festuca rubra (FR) on the biomass dynamics of the two species. The effects are listed in order of magnitude.

Input data	Increase in live biomass (g DM/m²)		Increase ratio
	AE	FR	AE/FR
reference :	610 (94%)	37 (6%)	16.4
SLA	344 (53%)	302 (47%)	1.1
VDLK/VDLV/HGT	517 (81%)	121 (19%)	4.3
EXTCF	526 (86%)	84 (14%)	6.2
VDLK/VDLV	562 (89%)	73 (11%)	7.7
HGT	573 (90%)	64 (10%)	9.0
Initial values (RT)	613 (93%)	46 (7%)	13.2
Initial values (SH)	687 (100%)	1 (0%)	520
FADM..	608 (97%)	17 (3%)	36.6
SRL	617 (95%)	34 (5%)	17.9

Initial values (RT) : The initial values of both dry weight and amount of nitrogen in the roots have been averaged.
Initial values (SH) : The initial values of both dry weight and amount of nitrogen in the shoot have been averaged.
FADM.. : Each dry matter allocation factor (RT, LV, ST and ER) has been averaged.

The effect of the total difference in the vertical distribution of the leaf area index, including the difference in height, has also been examined by averaging simultaneously the parameters of the vertical distribution function and the height development of the two species. It is similar to a simulation, in which only one horizontal leaf layer is distinguished, containing the total leaf area indices of both species. In this simulation the increase in live dry weight of Arrhenatherum is 4.3 times greater than that of Festuca (see VDLK/VDLV/HGT). This means that Arrhenatherum still grows at the expense of Festuca, because their ratio in mono culture equals 1.8.

The difference in the extinction coefficient of Arrhenatherum and Festuca has a greater effect on the biomass dynamics than the difference in vertical distribution of the leaf area index or the difference in height between the two species. An extinction coefficient of 0.55 for both species results in a increase ratio of 6.2 (see EXTCF), whereas averaging the parameters of the vertical distribution function (see VDLK/VDLV) or the height development (see HGT) gives a ratio of 7.7 and 9.0 respectively.

The high initial values of dry matter and nitrogen in the roots of Festuca have a negative effect on Festuca (see Initial Values (RT)). Apparently the high mortality rate in the reference simulation, due to a large amount of dry matter in the roots , is more important to the increase in live biomass, than the advantage of having a large root length index.

Three characteristics, in which the species differ, are favorable for Festuca and eliminating these differences leads to a higher increase ratio. When both species start with equal initial values of dry matter and nitrogen in the shoot, the increase in the biomass of Festuca amounts only 1 g DM/m² (see Initial Values (SH)). The increase ratio changes dramatically from 16.4 to 520, which is almost completely caused by equal dry weights of the leaves.

After averaging the dry matter allocation factors of both species, 97 % of the total increase in biomass comes from Arrhenatherum (see FADM..). This is mainly due to a decrease in the allocation of dry matter to the leaves of Festuca, which results in a decrease of the absorption of radiation.

The difference in the specific root length has only a small effect on the biomass dynamics. An equal specific root length results in a change of ± 1 % in the increase percentages of Arrhenatherum and Festuca. In the subroutine NITDIS the nitrogen uptake rate of each species has been calculated according to their relative root length indices, under the condition that the uptake rate does not exceed the rate of nitrogen demand. During the simulation the distribution of soil nitrogen among the species has been largely determined by their demands for nitrogen instead of their root length indices (compare RLI and RNUPER of both species in AEF881N.OUT & FRF881N.OUT, Appendix 6).

3.3.3 Identical characteristics

Some of the characteristics of Arrhenatherum and Festuca are assumed to be identical. The effect of this assumption on the biomass dynamics, has been studied by creating a difference between the species for each characteristic. The new values are calculated by a 10 % increase and decrease of the original value, which has been done simultaneously for both species. The total difference between the species becomes 20 % of the original value (see Table 3).

A difference in the maximum efficiency of the dry matter production has the greatest effect on the increases in live biomass, when compared to the other 'identical' characteristics. The increase ratio varies from 6.3 to 92.3, depending on which species has the highest efficiency (see EDMP).

Changing the relative death rates of roots or leaves affects a species at three levels : the rate of nitrogen loss through death of roots or leaves, the rate of dry matter loss and the remaining live dry weight of roots or leaves. It has almost no effect on the biomass dynamics, when the rate of nitrogen loss is raised or lowered with 10 % (see CNDLV and CNDRT). Under fertilised conditions the dynamics of Arrhenatherum and Festuca are more sensitive to a ± 10 % change in the relative death rates of leaves than to a similar change in the relative death rates of roots (see RDRLV and RDRRT).

Table 3 : The effect of a difference between the species in the characteristics, which are assumed to be identical, on the biomass dynamics of Arrhenatherum elatius (AE) and Festuca rubra (FR).
The new values of a characteristic equal ± 10 % of the old value and they create a difference between the two species of 20 % of the old value.
The effects are listed in order of magnitude.

Input data	Old value	New values AE	FR	Increase in live biomass (g DM/m²) AE	FR	Increase ratio AE/FR
		reference :		610 (94%)	37 (6%)	16.4
EDMP	3.0	3.3	2.7	694 (99%)	8 (1%)	92.3
(10-6)		2.7	3.3	508 (86%)	81 (14%)	6.3
RDRLV	0.015	0.0165	0.0135	589 (92%)	49 (8%)	11.9
		0.0135	0.0165	630 (96%)	26 (4%)	24.0
FOPMX	0.65	0.715	0.585	570 (93%)	42 (7%)	13.4
		0.585	0.715	661 (96%)	29 (4%)	22.5
RDRRT	0.010	0.011	0.009	606 (94%)	42 (6%)	14.4
		0.009	0.011	615 (95%)	33 (5%)	18.9
CN..MX		* 1.1	* 0.9	632 (95%)	37 (5%)	17.3
		* 0.9	* 1.1	587 (94%)	38 (6%)	15.4
CNDLV	0.005	0.0055	0.0045	610 (94%)	37 (6%)	16.4
		0.0045	0.0055	611 (94%)	37 (6%)	16.5
CNDRT	0.005	0.0055	0.0045	611 (94%)	37 (6%)	16.4
		0.0045	0.0055	610 (94%)	37 (6%)	16.5

CN..MX : The maximum concentrations of nitrogen in the various plant parts (RT,LV,ST and ER) have been multiplied with 1.1 and 0.9 in the subroutine NITDEM.

A difference in the optimum nitrogen concentration has been created by changing the factor, which relates this optimum concentration to the maximum nitrogen concentration of each species. The increase ratio equals 13.4, when Arrhenatherum has the highest optimum nitrogen concentration and it equals 22.5, when Arrhenatherum has the lowest optimum nitrogen concentration (see FOPMX).

A difference between the species in the maximum nitrogen concentrations of each plant part causes the increase ratio to vary from 15.4 to 17.3 (see CN..MX). This difference has been created in such a way, that only changes the demand for nitrogen with ± 10 %, whereas it does not affect the optimum nitrogen concentration of both species.

4. Discussion & conclusions

4.1 Discussion

4.1.1 Model assumptions

The major model assumptions are listed in Appendix 1. Some of them are discussed in this paragraph (the numbers refer to Appendix 1).

1. It is not possible to verify the first major model assumption, because the difference between plant features in mono culture and those in mixed culture has not been determined. The input data, which have been derived from the experiment at the Sinderhoeve, originate from the mono cultures and corresponding data from the mixed stand have not been measured. The sensitivity analysis, however, clearly shows, that a possible difference can have an effect on the biomass dynamics of Arrhenatherum and Festuca in mixture.

2. It is unknown, whether other resources, except radiation and nitrogen, have also limited the production of the species in the simulated period. A suboptimum phosphor supply or water shortage is very well feasible, because the soil at the Sinderhoeve can be characterized as poor and sandy. When more than one soil resource has limited the production, it would probably have changed the increase ratio of Arrhenatherum with respect to Festuca.

3. The extinction of radiation in a field situation results from the absorption and reflection characteristics of all above ground plant parts (live and dead). The presence of these plant parts is different in each layer and also varies in time. In this model the total extinction is only related to the leaf area index of live leaves, using an averaged extinction coefficient for each layer and for the whole simulation period. This is only valid if the variation in the actual extinction coefficient in each layer and at each day is negligible compared to its influence on the biomass development. The impact of this simplification is not known.

4. In this model only the vertical distribution of the leaf area index has been considered. It has been assumed that, within each horizontal layer, the leaf area index and therefore also the transmission of radiation are distributed homogeneously. However a clustered distribution is more likely, because the leaves of an individual plant are positioned round its central axis. A leaf has a greater chance to shade leaves of the same individual than to shade leaves of other individuals. Assuming a homogeneous distribution, results in an overestimation of the absorption of radiation in a mixed culture, if a species has its leaves at greater heights and in an underestimation for the 'lower' species (see also Van Gerwen et al., 1987).

This effect will become worse, as the model contains more horizontal layers. On the other hand, more horizontal layers gives a better simulation of the difference in the vertical distribution of the leaf area index of the species. The number of horizontal layers (NL) is set at three to balance between an overestimation and an underestimation of the production of Arrhenatherum (the 'highest' species). The overestimation is caused by assuming a homogeneous distribution of the leaf area index and an underestimation is caused by having too few horizontal leaf layers to account for differences in the vertical distibution. Another reason for NL = 3 is discussed below (see 5).

The sensitivity of the model to the number of layers is given in Table 4.

Table 4 : The effect of the number of horizontal leaf layers on the biomass dynamics of Arrhenatherum elatius (AE) and Festuca rubra (FR).

Number of layers	Value	Increase in live biomass (g DM/m²) AE	FR	Increase ratio AE/FR
NL =	2	538 (86%)	89 (14%)	6.0
NL =	3 (reference)	610 (94%)	37 (6%)	16.4
NL =	4	625 (96%)	29 (4%)	21.8

NL=2 : Under a top layer with only leaves of Arrhenatherum, there is one bottom layer with leaves of both species. Boundaries : HGT(AE) & HGT(FR).

NL=4 : Under a top layer with only leaves of Arrhenatherum, there are three bottom layers with leaves of both species. Boundaries : HGT(AE), HGT(FR), 2/3 * HGT(FR) & 1/3 * HGT(FR) (compare NL=3 at page 9).

5. The maximum efficiency of the dry matter production is based on literature data, concerning the absorption of radiation and the production of dry matter by a whole vegetation. In simulating the mixed culture, the maximum efficiency is used as a constant for parts of the vegetation, i.e. the horizontal leaf layers. This is only valid, when possible differences in the efficiencies between the horizontal layers, are neglible. To minimize a possible deviation, caused by using an average instead of the actual efficiency in each horizontal layer, the number of layers has been limited to three.

6. The optimum concentration of nitrogen in leaves, which is calculated as the product of the maximum nitrogen concentration with a constant factor (FOPMX), should not be equal for both species. In a mixed culture the lower species (Festuca rubra) absorbs less radiation per unit of leaf area, per second, as compared to the higher species (Arrhenatherum elatius). It will therefore be satisfied with a lower nitrogen concentration in producing its dry matter at maximum efficiency (see also page 18). This could be modelled by lowering the factor, which relates the optimum to the maximum nitrogen concentration (FOPMX), of Festuca with respect to that of Arrhenatherum. Under fertilized conditions a smaller factor for Festuca will have little effect on the biomass development of the species, because the dry matter production of this species was at most times not limited by a suboptimum nitrogen concentration.

4.1.2 Model behaviour

The model has been used to simulate the dynamics of Arrhenatherum and Festuca in a mixed stand. A validation of the model, by comparing the simulation results with experimental data, is a test on the model equations and on the model input data, whether the equations are satisfactory in approximating the real processes and whether the input data have the correct values. Because none of the species characteristics, which are used as input data, have been derived from the mixed culture and because the difference in plant features between mono culture and mixed culture is unknown, the model equations can not be verified with the data from the experiment at the Sinderhoeve. It can not be determined, whether a possible deviation of the simulation results from the experimental data, is caused by incorrect input data or by false model equations. More data should have been gathered at the mixed culture, of which only the standing biomass of each species, above mowing height, has been measured at the 6th of June.

The sensitivity analysis has been performed with the model under fertilized conditions and refers to the development in a period of 71 days (28 March - 6 June 1988). The effects of the input data on the biomass dynamics, as listed in the tables 1,2,3 and 4, are restricted to these circumstances. An unfertilized environment will certainly change the sensitivity of the model to the input data.

During the simulation Arrhenatherum and Festuca lose approximately the same amount of dry matter through mortality of roots and leaves (AE : 105 g/m^2 and FR : 104 g/m^2 ; see Appendix 6). Another part of the live biomass is lost through mowing. At the end of the reference simulation the shoot dry weight of Arrhenatherum equals 611 g/m^2 and that of Festuca 94 g/m^2. Most of the shoot is lost through mowing, which means that Arrhenatherum will ultimately lose more dry matter than Festuca. This will also change the ratio between the increases in live biomass of both species.

4.2 Conclusions

The simulation results have not yet been compared with the experimental data, because the parameterisation has not been completed and data on the nitrogen concentrations were not known during this study (see also 4.3 : Further Research). The conclusions in this paragraph are based on computer simulations.

Under fertilized conditions, until the first cut in June, Arrhenatherum elatius grows at the expense of Festuca rubra in a simulated mixed stand. The ratio between the increase in live biomass of Arrhenatherum with respect to that of Festuca equals 1.8 in the simulated mono cultures, but changes into 16.4 in a simulated mixed stand. The loss of dry matter is approximately equal for both species, but Arrhenatherum produces more dry matter, because it absorbs most of the radiation and most of the nitrogen. The fertilisation enables Arrhenatherum to produce at maximum efficiency, which results in a high leaf area index. Arrhenatherum overtops Festuca with this large amount of radiation absorbing leaf area and lowers the availability of radiation for Festuca. This leads to a stong decrease in the production of Festuca. The unequal distribution of radiation also affects the distribution of nitrogen for the benefit of Arrhenatherum. Although Festuca has a greater ability to take up the nitrogen from the soil, according to its root length index, it absorbs only a small part of the available soil nitrogen, because its low production, relative to the high nitrogen availability, cause a low demand for nitrogen. Most of the nitrogen is left over and is absorbed by Arrhenatherum, which has a high demand for nitrogen in order to maintain its nitrogen concentration.

The sensitivity analysis on resource availability shows that both species are limited by the availability of global radiation, but only Arrhenatherum is also limited by the nitrogen supply in the soil. Arrhenatherum benefits with respect to Festuca from an earlier date of fertilisation, a higher nitrogen availability and a lower availability of the global radiation, whereas Festuca is favored by a later date of fertilisation, a lower nitrogen availability and a higher availability of the global radiation.

The sensitivity to the characteristics, in which the species differ, shows that the differences in the features, which determine the vertical position of the leaf area index (HGT, VDLK and VDLV), are less important in the competition for radiation, than the differences in the features, concerning the magnitude of the leaf area index in absorbing radiation (f.i. SLA & EXTCF). Moreover the model is very sensitive to the initial values of dry matter and nitrogen in the shoot of Arrhenatherum and Festuca. When the species start with equal shoot dry weight, the increase in live biomass of Festuca drops from 37 g/m^2 in the reference simulation to 1 g/m^2 and the increase ratio becomes 520.

The sensitivity to the characteristics, which are assumed to be identical for both species, shows that a possible difference in the maximum efficiency of the dry matter production (EDMP) has a great effect on the dynamics of Arrhenatherum and Festuca. Under fertilized conditions the biomass dynamics are more sensitive to a difference in the relative death rate of the leaves than to a similar difference in the relative death rate of the roots.

4.3 Further research

The extinction coefficient (EXTCF) and the maximum efficiency of the dry matter production (EDMP) are key factors in simulating the production of dry matter. The extinction coefficient links the leaf area index to the absorbtion of radiation and the efficiency links the absorbtion to the production of dry matter. In the present model both parameters are based on data from literature, but they will be derived from experimental data. Measurements on the extinction of radiation and the leaf area index will be conducted at the Sinderhoeve in June 1989. To determine the maximum efficiency the total production has to be known. An estimation of the loss of biomass through decomposition of dead roots and dead leaves is necessary to correct the biomass data, which have been measured at the Sinderhoeve, and to calculate the total production. Through a linear regression of the production data, as the response variable, on the absorbtion data, the maximum efficiency can be calculated under the condition that the nitrogen concentration does not limit the production. The corrected biomass data are also needed to determine the dry matter allocation factors (FADM..) and the relative death rate of leaves (RDRLV).

When the nitrogen concentrations of the various plant parts are available, the following input data can be adjusted : the rate of nitrogen supply through mineralisation (RNSM), the nitrogen recovery factor from the fertilisation (NRECOV), the initial amounts of nitrogen in roots, leaves and stems of both species (ANRT, ANLV and ANST) and the concentrations of nitrogen in dead leaves (CNDLV).

This simulation study on the dynamics of Arrhenatherum and Festuca in mixed stand can be extended in two directions. Further research on the effect of cutting on the biomass dynamics or examining, which plant features are most successful under nutrient-poor conditions.

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1. The difference between plant features in mono culture and those in mixed culture, has no influence on the dynamics of the species in mixture (Introduction).
2. Only radiation and nitrogen are limiting resources. The absorption of these resources determine the production of dry matter (Introduction).
3. The use of one average extinction coefficient for each horizontal layer and for the whole simulation period does not change the biomass development of the competing species. (ABSRAD)
4. The leaf area index is distributed homogeneously within each horizontal layer (ABSRAD).
5. The maximum efficiency of the dry matter production is constant during the whole simulation period and equal in each of the three horizontal leaf layers (DRYMAT).
6. Each species distributes its leaf nitrogen over all live leaves in order to maximize the dry matter production (DRYMAT).
7. The rate of dry matter loss through death of roots and leaves is a constant fraction of their dry weights (DRYMAT).
8. The absorption characteristics per unit of root length are equal for both species (NITDIS).
9. The actual nitrogen allocation factor is approximately equal to the relative maximum amount of nitrogen in each organ (NITDIS).

```
*-------------------------------------------------------------------*
* Program  : COMPETITION                                            *
*                                                                   *
* Author   : J.G. Conijn                                            *
* Date     : 31 March 1989                                          *
*                                                                   *
* Purpose  : The program COMPETITION simulates the effect of nitrogen *
*            availability on the competition between plant species.  *
*            The model calculates the biomass development as a result *
*            of distributing radiation and nitrogen among the competing*
*            species.                                               *
*                                                                   *
* Structure: All computations are performed by calling subroutines  *
*            from the main program. In these subroutines some of the *
*            calculations are executed by using functions.          *
*                                                                   *
* Subroutine                                                        *
*                                                                   *
* READIN : Reading of the specific data                             *
* WEATHR : Reading of daily weather data                            *
* VDLEAF : Calculation of the vertical distribution of leaf area index *
* ABSRAD : Calculation of the amount of radiation, absorbed per species*
* DRYMAT : Calculation of the dry matter production and distribution *
*          rates                                                    *
* NITDEM : Calculation of the nitrogen demand of each species       *
* NITDIS : Calculation of the nitrogen availability in the soil and *
*          the uptake and distribution rates of nitrogen            *
* OUTPUT : Writing of the results of the simulation in output files *
* INTGRT : Integration of all state variables in time               *
*                                                                   *
* Function                                                          *
*                                                                   *
* SUM    : Summation of a variable over all species                 *
* LINT   : Linear interpolation of data points                      *
*-------------------------------------------------------------------*


      PROGRAM COMPETITION


*-------------------------------------------------------------------*
*     Declarations of variables.                                    *
*-------------------------------------------------------------------*

*-----The program begins with the type declarations of the variables.
*     All variables beginning with the letter A,B...Y,Z are REAL,
*     except those who are explicitly declared as INTEGER or CHARACTER.

      IMPLICIT REAL (A-Z)
      INTEGER NS, NL, D,ND, DAY,
     $        NDVDLV,NDHGT,NDLAI,NDFADM,NDWTOT,NDSLA,NDCNMX
      CHARACTER FLNAME*6,TITLE*60,ANSW1*1,ANSW2*1
```

```
*-----------------------------------------------------------------------*
*     Parameters, which are used in the DIMENSION statements.          *
*-----------------------------------------------------------------------*

*-----The number of species (NS) and the number of horizontal leaf-
*     layers (NL) remain constant throughout an entire simulation run.
*     ND is the maximum number of X and Y data in the tables, which are
*     used for the interpolation function.

      PARAMETER (NS  =  2,
     $           NL  =  3,
     $           ND  = 16)


*-----------------------------------------------------------------------*
*     Array's.                                                          *
*-----------------------------------------------------------------------*

*-----The organisation of variables in array's is declared with the
*     DIMENSION statement.


      DIMENSION FLNAME(NS),TITLE(NS),EXTCF(NS),EDMP(NS),
     $          RDRRT(NS),RDRLV(NS),CNDRT(NS),CNDLV(NS),
     $          SRL(NS),VDLK(NS),VDLVTB(NS,ND),
     $          HGTTB(NS,ND),NDLAI(NS),LAITB(NS,ND),
     $          FAMRTT(NS,ND),FAMLVT(NS,ND),FAMSTT(NS,ND),FAMERT(NS,ND),
     $          SLATB(NS,ND),WTOTTB(NS,ND),
     $          WRT(NS),WLV(NS),WST(NS),WDRT(NS),WDLV(NS),
     $          WLB(NS),WDB(NS),WTOT(NS),
     $          ANRT(NS),ANLV(NS),ANST(NS),ANLB(NS),
     $          CNRT(NS),CNLV(NS),CNST(NS),RLI(NS),LAI(NS)
      DIMENSION HGT(NS),LAILAY(NS,NL),CHKLAI(NS)
      DIMENSION RADABS(NS),RADPER(NS)
      DIMENSION RDMP(NS),REDN(NS),RDMLRT(NS),RDMLLV(NS),
     $          NFDMRT(NS),NFDMLV(NS),NFDMST(NS),NFDMER(NS)
      DIMENSION ANRTMX(NS),ANLVMX(NS),ANSTMX(NS),ANERMX(NS),ANLBMX(NS),
     $          RNLRT(NS),RNLLV(NS),RNDLB(NS)
      DIMENSION RNU(NS),RNUPER(NS),
     $          FANRT(NS),FANLV(NS),FANST(NS),FANER(NS),
     $          NFNLB(NS),NFNDB(NS)
      DIMENSION WER(NS),CHKWTT(NS),
     $          ANER(NS),ANDB(NS),CNER(NS)
```

```
*-----------------------------------------------------------------*
*     Non-specific data.                                          *
*-----------------------------------------------------------------*


*-----For the reflection coefficient (REFLCF) a constant value is used.

      PARAMETER (REFLCF = 0.08)


*-----Parameters for determining the rate of nitrogen supply.

      PARAMETER (RNSM   = 0.05,
     $           NGDATE = 12.,
     $           NGIFT  = 10.,
     $           NRECOV = 0.55)


*-----Parameters for determining the reduction on the dry matter
*     production, caused by suboptimum nitrogen concentrations

      PARAMETER (CNLVMN = 0.008,
     $           FOPMX  = 0.65)


*-----Part of the root biomass (FRTN) is present as a stump.

      PARAMETER (FRTN = 0.26)


*-----Number of data of the table containing the maximum nitrogen
*     concentrations of the plant parts.

      PARAMETER (NDCNMX = 4)

*-----The maximum nitrogen concentrations in the various plant parts
*     do not remain constant during the simulation period, but they
*     are equal for all species.

      DIMENSION CNRTXT(NS,NDCNMX),CNLVXT(NS,NDCNMX),
     $          CNSTXT(NS,NDCNMX),CNERXT(NS,NDCNMX)


      DATA (CNRTXT(1,D),D=1,NDCNMX) / 1.,0.015,71.,0.010 /
      DATA (CNLVXT(1,D),D=1,NDCNMX) / 1.,0.055,71.,0.035 /
      DATA (CNSTXT(1,D),D=1,NDCNMX) / 1.,0.025,71.,0.015 /
      DATA (CNERXT(1,D),D=1,NDCNMX) / 29.,0.045,71.,0.040 /
```

```
*-------------------------------------------------------------------*
*     Specific data.                                                *
*-------------------------------------------------------------------*

*-----  AEF881 = Arrhenatherum elatius ; fertilized/till 1st cut ; 1988
*       FRF881 = Festuca rubra         ; fertilized/till 1st cut ; 1988


      FLNAME(1) = 'AEF881'
      FLNAME(2) = 'FRF881'


      CALL READIN (NS,ND,FLNAME,TITLE,ANSW1,ANSW2,
     $             EXTCF,EDMP,RDRRT,RDRLV,CNDRT,CNDLV,
     $             SRL,VDLK,NDVDLV,VDLVTB,
     $             NDHGT,HGTTB,NDLAI,LAITB,
     $             NDFADM,FAMRTT,FAMLVT,FAMSTT,FAMERT,
     $             NDSLA,SLATB,NDWTOT,WTOTTB,
     $             WRT,WLV,WST,WDRT,WDLV,WLB,WDB,WTOT,
     $             ANRT,ANLV,ANST,ANLB,CNRT,CNLV,CNST,
     $             FRTN,RLI,LAI)

*-------------------------------------------------------------------*
*     Time conditions.                                              *
*-------------------------------------------------------------------*

*-----TIME begins with the value 1 referring to the first harvest day.
*     Each time step TIME is updated with DELT until TIME reaches
*     FINTIM, i.e. the day of the final harvest.

      DATA TIME,FINTIM,DELT / 1.,71.,1. /


*-------------------------------------------------------------------*
*     Dynamic simulation.                                           *
*-------------------------------------------------------------------*


10    IF (TIME .LE. FINTIM) THEN


        CALL WEATHR (TIME,FINTIM,DAY,TAMIN,TAMAX,RADGLB)


        CALL VDLEAF (NS,NL,TIME,LAI,HGT,NDHGT,HGTTB,VDLK,
     $               NDVDLV,VDLVTB,LAILAY,CHKLAI)


        CALL ABSRAD (NS,NL,RADGLB,EXTCF,LAILAY,REFLCF,RADABS,
     $               RADPER,CHKRAD)
```

```
      CALL DRYMAT (NS,ANSW1,TIME,DELT,NDWTOT,WTOTTB,RDMP,
     $             NDCNMX,CNLVXT,FOPMX,CNLVMN,CNLV,REDN,RADABS,
     $             EDMP,NDFADM,FAMRTT,FAMLVT,FAMSTT,FAMERT,
     $             WRT,RDRRT,RDMLRT,WLV,RDRLV,RDMLLV,
     $             NFDMRT,NFDMLV,NFDMST,NFDMER)

      CALL NITDEM (NS,TIME,DELT,
     $             NDCNMX,CNRTXT,CNLVXT,CNSTXT,CNERXT,
     $             WRT,WLV,WST,WER,
     $             NFDMRT,NFDMLV,NFDMST,NFDMER,
     $             ANRTMX,ANLVMX,ANSTMX,ANERMX,ANLBMX,
     $             RDMLRT,CNDRT,RNLRT,RDMLLV,CNDLV,RNLLV,
     $             ANLB,RNDLB)

      CALL NITDIS (NS,TIME,DELT,RNSM,ANSL,
     $             RNDLB,RLI,RNU,RNUPER,
     $             ANRTMX,ANLVMX,ANSTMX,ANERMX,ANLBMX,
     $             FANRT,FANLV,FANST,FANER,
     $             RNLRT,RNLLV,NFNLB,NFNDB)

      CALL OUTPUT (NS,TIME,FINTIM,FLNAME,TITLE,
     $             DAY,LAI,HGT,RADABS,RADPER,
     $             WRT,WLV,WST,WER,WDRT,WDLV,WLB,WTOT,
     $             ANSL,RLI,RNU,RNUPER,CNRT,CNLV,REDN,ANLB,ANDB,
     $             CHKLAI,CHKRAD,CHKWTT,CHKNIT)

      CALL INTGRT (NS,ND,TIME,DELT,ANSW2,RDMP,
     $             NFDMRT,NFDMLV,NFDMST,NFDMER,RDMLRT,RDMLLV,
     $             WTOT,WRT,WLV,WST,WER,WDRT,WDLV,WLB,WDB,CHKWTT,
     $             SRL,FRTN,RLI,NDLAI,LAITB,NDSLA,SLATB,LAI,
     $             ANLB,ANRT,ANLV,ANST,ANER,ANDB,
     $             NFNLB,NFNDB,FANRT,FANLV,FANST,FANER,
     $             CNRT,CNLV,CNST,CNER,
     $             NGDATE,NGIFT,NRECOV,RNU,ANSL,RNSM,CHKNIT)

      TIME = TIME + DELT
      GOTO 10

    ENDIF

    STOP  'END OF SIMULATION : TIME HAS REACHED FINTIM !'
    END
```

```
*-------------------------------------------------------------------*
* Subprogram : READIN                                               *
*                                                                   *
* Purpose    : The subprogram READIN reads parameters, tables and the *
*              initial values of the state variables of each species *
*              from input files (extension : .DAT).                 *
*-------------------------------------------------------------------*

      SUBROUTINE READIN (NS,ND,FLNAME,TITLE,ANSW1,ANSW2,
     $                   EXTCF,EDMP,RDRRT,RDRLV,CNDRT,CNDLV,
     $                   SRL,VDLK,NDVDLV,VDLVTB,
     $                   NDHGT,HGTTB,NDLAI,LAITB,
     $                   NDFADM,FAMRTT,FAMLVT,FAMSTT,FAMERT,
     $                   NDSLA,SLATB,NDWTOT,WTOTTB,
     $                   WRT,WLV,WST,WDRT,WDLV,WLB,WDB,WTOT,
     $                   ANRT,ANLV,ANST,ANLB,CNRT,CNLV,CNST,
     $                   FRTN,RLI,LAI)

      IMPLICIT REAL (A-Z)
      INTEGER S,NS,D,ND,
     $        NDVDLV,NDHGT,NDLAI,NDFADM,NDSLA,NDWTOT
      CHARACTER FLNAME*6,TITLE*60,ANSW1*1,ANSW2*1

      DIMENSION FLNAME(NS),TITLE(NS),EXTCF(NS),EDMP(NS),
     $          RDRRT(NS),RDRLV(NS),CNDRT(NS),CNDLV(NS),
     $          SRL(NS),VDLK(NS),VDLVTB(NS,ND),
     $          HGTTB(NS,ND),NDLAI(NS),LAITB(NS,ND),
     $          FAMRTT(NS,ND),FAMLVT(NS,ND),FAMSTT(NS,ND),FAMERT(NS,ND),
     $          SLATB(NS,ND),WTOTTB(NS,ND),
     $          WRT(NS),WLV(NS),WST(NS),WDRT(NS),WDLV(NS),
     $          WLB(NS),WDB(NS),WTOT(NS),
     $          ANRT(NS),ANLV(NS),ANST(NS),ANLB(NS),
     $          CNRT(NS),CNLV(NS),CNST(NS),RLI(NS),SLA(4),LAI(NS)


      DO 10 S=1,NS

*-----Initialisation of the subroutine by opening a file with the name
*     FLNAME.DAT. This file contains specific data from mono culture
*     and literature.

        OPEN (UNIT=10,FILE=FLNAME(S) // '.DAT',STATUS='OLD')

*-----The title of the file is read ; the comment lines and the names
*     of the parameters and variables are skipped by the READ statements
*     containing a slash (/) and the code 15X.

        READ (10,'(A)') TITLE(S)
        READ (10,'(/,/,/)')
```

```
      READ (10,'(15X,F10.3)') EXTCF(S)
      READ (10,'(15X,F10.3)') EDMP(S)
      READ (10,'(15X,F10.3)') RDRRT(S)
      READ (10,'(15X,F10.3)') RDRLV(S)
      READ (10,'(15X,F10.3)') CNDRT(S)
      READ (10,'(15X,F10.3)') CNDLV(S)
      READ (10,'(15X,F10.3)') SRL(S)
      READ (10,'(15X,F10.3)') VDLK(S)
      READ (10,'(/)')
      READ (10,'(15X,I10)') NDVDLV
      READ (10,*) (VDLVTB(S,D),D=1,NDVDLV)
      READ (10,'(A)')
      READ (10,'(15X,I10)') NDHGT
      READ (10,*) (HGTTB(S,D),D=1,NDHGT)
      READ (10,'(A)')
      READ (10,'(15X,I10)') NDLAI(S)
      READ (10,*) (LAITB(S,D),D=1,NDLAI(S))
      READ (10,'(A)')
      READ (10,'(15X,I10)') NDFADM
      READ (10,*) (FAMRTT(S,D),D=1,NDFADM)
      READ (10,'(A)')
      READ (10,'(15X,I10)') NDFADM
      READ (10,*) (FAMLVT(S,D),D=1,NDFADM)
      READ (10,'(A)')
      READ (10,'(15X,I10)') NDFADM
      READ (10,*) (FAMSTT(S,D),D=1,NDFADM)
      READ (10,'(A)')
      READ (10,'(15X,I10)') NDFADM
      READ (10,*) (FAMERT(S,D),D=1,NDFADM)
      READ (10,'(A)')
      READ (10,'(15X,I10)') NDSLA
      READ (10,*) (SLATB(S,D),D=1,NDSLA)
      READ (10,'(A)')
      READ (10,'(15X,I10)') NDWTOT
      READ (10,*) (WTOTTB(S,D),D=1,NDWTOT)
      READ (10,'(/)')
      READ (10,'(15X,F10.3)') WRT(S)
      READ (10,'(15X,F10.3)') WLV(S)
      READ (10,'(15X,F10.3)') WST(S)
      READ (10,'(15X,F10.3)') WDRT(S)
      READ (10,'(15X,F10.3)') WDLV(S)
      READ (10, '(A)')
      READ (10,'(15X,F10.3)') ANRT(S)
      READ (10,'(15X,F10.3)') ANLV(S)
      READ (10,'(15X,F10.3)') ANST(S)

*-----The input file is closed again.

      CLOSE (10)

10    CONTINUE
```

```
      DO 20 S=1,NS

*-----When a mixed culture with NS species is simulated, the values
*     of the state variables are assumed to be equal to those, measured
*     in mono culture, divided by NS.

        WRT(S)  =  WRT(S) / NS
        WLV(S)  =  WLV(S) / NS
        WST(S)  =  WST(S) / NS
        WDRT(S) = WDRT(S) / NS
        WDLV(S) = WDLV(S) / NS

        WLB(S)  =  WRT(S) + WLV(S) + WST(S)
        WDB(S)  =  WDRT(S) + WDLV(S)
        WTOT(S) =  WDB(S) + WLB(S)

        ANRT(S) = ANRT(S) / NS
        ANLV(S) = ANLV(S) / NS
        ANST(S) = ANST(S) / NS

        ANLB(S) = ANRT(S) + ANLV(S) + ANST(S)

*-----Part of the roots (FRTN) is present as a stump.

        RLI(S)  = WRT(S) * (1. - FRTN) * SRL(S)

        SLA(S)  = LINT(S,NS,NDSLA,SLATB,1.)
        LAI(S)  = WLV(S) * SLA(S)

        CNRT(S) = ANRT(S) / WRT(S)
        CNLV(S) = ANLV(S) / WLV(S)
        CNST(S) = ANST(S) / WST(S)

20    CONTINUE


*-----A choice can be made, whether the rate of dry matter production
*     or the leaf area index become forcing variables in stead of
*     being computed by the program.
*     Data on biomass development and leaf area index have only been
*     gathered in mono culture.

      IF (NS .EQ. 1) THEN

*-----Rate of dry matter production.

30    WRITE (*,'(/A/A/A/A/A )')
     $' Do you want the rate of dry matter production to be a forcing',
     $' variable ? This means that the production rate is not computed',
     $' but derived from the experiment by linear interpolation of',
     $' harvest data.',
     $' Answer (Y/N) : '

      READ (*,'(A)') ANSW1
```

```
      IF ((ANSW1 .NE. 'Y') .AND. (ANSW1 .NE. 'y') .AND.
     $    (ANSW1 .NE. 'N') .AND. (ANSW1 .NE. 'n')) GOTO 30


*-----Leaf area index.

40      WRITE (*,'(/A/A )')
     $  ' Do you want the leaf area index to be a forcing variable ?',
     $  ' Answer (Y/N) : '

        READ (*,'(A)') ANSW2

        IF ((ANSW2 .NE. 'Y') .AND. (ANSW2 .NE. 'y') .AND.
     $      (ANSW2 .NE. 'N') .AND. (ANSW2 .NE. 'n')) GOTO 40

      ENDIF

      RETURN
      END
```

```
*-----------------------------------------------------------------------*
* Subprogram : WEATHR                                                   *
*                                                                       *
* Purpose    : The subprogram WEATHR reads weather data from an         *
*              input file (WTHR88.DAT).                                 *
*-----------------------------------------------------------------------*

      SUBROUTINE WEATHR (TIME,FINTIM,DAY,TAMIN,TAMAX,RADGLB)

      IMPLICIT REAL (A-Z)
      INTEGER DAY

*-----Initialisation of the subroutine by opening the file 'WTHR88.DAT'
*     and skipping the three comment lines at the top of the file.

      IF (TIME .EQ. 1.) THEN
        OPEN (UNIT=10,FILE='WTHR88.DAT',STATUS='OLD')
        READ (10,'(/,/)')
      ENDIF

*-----Each day the minimum and maximum air temperature (TAMIN , TAMAX)
*     and the daily total of global radiation (RADGLB) are read.
*     DAY is the day number in a Julian calender (DAY=1 at 1 January).

      READ (10,*) DAY,TAMIN,TAMAX,RADGLB

*-----The input file is closed again when TIME equals FINTIM.

      IF (TIME .EQ. FINTIM) THEN
        CLOSE (10)
      ENDIF

      RETURN
      END
```

```
*-----------------------------------------------------------------*
* Subprogam : VDLEAF                                              *
*                                                                 *
* Purpose   : The subprogram VDLEAF divides the vegetation into   *
*             horizontal layers and calculates the leaf area index *
*             of each species per layer : LAILAY(S,L).            *
*-----------------------------------------------------------------*

      SUBROUTINE VDLEAF (NS,NL,TIME,LAI,HGT,NDHGT,HGTTB,VDLK,
     $                   NDVDLV,VDLVTB,LAILAY,CHKLAI)

      IMPLICIT REAL (A-Z)
      INTEGER S,S1,S2,NS,L,NL,NDHGT,NDVDLV,RANK

      DIMENSION LAI(NS),HGT(NS),HGTTB(NS,NDHGT),HGTLAY(5),
     $          VDLK(NS),VDLV(4),VDLVTB(NS,NDVDLV),
     $          HGTREL(5),LAIREL(6),LAILAY(NS,NL),CHKLAI(NS)


*-----The height of each species is determined by linear interpolation
*     of harvest data.

      DO 10 S=1,NS

        HGT(S) = LINT(S,NS,NDHGT,HGTTB,TIME)

10    CONTINUE

*-----If only one species is present, only one layer is created with
*     a leaf area index (LAILAY) equal to the total leaf area index of
*     that species (LAI).

      IF (NS .EQ. 1) THEN
        LAILAY(NS,1) = LAI(NS)
        RETURN
      ENDIF


*-----Initialisation of the boundaries between the horizontal layers
*     (HGTLAY). For explanation, see below.

      DO 15 L=1,NS

        HGTLAY(L) = 250.

15    CONTINUE
```

```
*-----The height of each species is compared with the heights of all
*     competing species. The highest species will get a RANK of 1,
*     whereas the lowest species will get a RANK equal to NS.

      DO 30 S1=1,NS

*-----Initialisation of RANK.

        RANK = NS

        DO 20 S2=1,NS

          IF (HGT(S1) .GT. HGT(S2)) THEN
            RANK = RANK - 1
          ENDIF

20      CONTINUE

*-----The heights of the competing species (HGT) are the boundaries
*     (HGTLAY) between the horizontal layers.
*     The highest species (RANK = 1) sets the upper boundary of the
*     top layer (L = 1) ; the height of the second highest species
*     sets the upper boundary of layer nr. 2 (RANK = 2, L = 2); etc.
*     The number of layers, created in this way, equals NS.
*     An additonal layer is created by setting its upper boundary
*     at half-height of the lowest species (RANK = NS, L = NS+1 = NL).

        L = RANK
        HGTLAY(L) = HGT(S1)

        IF (RANK .EQ. NS) THEN
          HGTLAY(NL) = HGT(S1) / 2.
        ENDIF

30    CONTINUE

*-----If two species have the same height, one of the RANK numbers
*     from 1 to NS will be skipped. At the same time one of the
*     layers can be omitted. This situation is simulated by
*     setting the default layer heights far beyond a normal value :
*     250 cm. When each RANK number is asssigned to a layer number,
*     all layer heights will be rewrited to the real values,
*     except the one with the RANK number, that has been skipped.
*     This layer contains no biomass because of its upper (250) and
*     lower (height of the highest species) boundary and it will act
*     as if it has been omitted.
```

```
*-----The relative leaf area index (LAIREL) beneath a relative height
*     (HGTREL) is calculated by means of a function with 2 parameters :
*     VDLK and VDLV. Only VDLV varies in TIME.

      DO 60 S=1,NS

        VDLV(S) = LINT (S,NS,NDVDLV,VDLVTB,TIME)

        DO 40 L=1,NL

          IF (HGTLAY(L) .GT. HGT(S)) GOTO 40

          HGTREL(L) = HGTLAY(L)/HGT(S)
          LAIREL(L) = 1. / (1. + EXP(-VDLK(S)*(HGTREL(L) - VDLV(S))))

*-----Two IF statements are used to set the upper and lower limits
*     of the function.
*     1. If the height of a species (HGT) equals the upper boundary
*     of a layer (HGTLAY), the total relative leaf area index of this
*     species is beneath this layer height.
*     2. At groundlevel (NL + 1) the relative leaf area index equals 0.0
*     for all species.


          IF ((HGT(S) - HGTLAY(L)) .LT. 1.E-10) LAIREL(L)   = 1.
          IF (L .EQ. NL)                        LAIREL(L+1) = 0.

40      CONTINUE

*-----If a species has no leaves in a layer, the leaf area index
*     of this species in this layer equals 0.0 . In all other cases
*     the leaf area index (LAILAY) is calculated by taking the product of
*     the leaf area index of a species (LAI) with the difference
*     between the relative leaf area index beneath the upper boundary of
*     this layer (LAIREL(L)) and the relative leaf area index beneath the
*     upper boundary of the next layer (LAIREL(L+1)).


        DO 50 L=1,NL

          IF (HGTLAY(L) .GT. HGT(S)) THEN
            LAILAY(S,L) = 0.
          ELSE
            LAILAY(S,L) = LAI(S) * (LAIREL(L) - LAIREL(L+1))
          ENDIF

50      CONTINUE

60    CONTINUE
```

```
*-----The distribution of leaf area is checked by taking the
*     difference between the total leaf area index of a species (LAI)
*     and the sum of the leaf area indices of each layer (TOTAL).
*     This difference (CHKLAI) is expressed as a percentage of the
*     leaf area index of a species.
*     The calculations are also checked on negative values for the
*     leaf area index.

      DO 80 S=1,NS

*----Initialisation of TOTAL.

        TOTAL = 0.

        DO 70 L=1,NL

          TOTAL = TOTAL + LAILAY(S,L)

          IF (LAILAY(S,L) .LT. 0.) THEN
            WRITE (*,'(A/F5.0,2(I5))')
     $      ' The leaf area index of species S in layer L is negative !',
     $        TIME,S,L
          ENDIF

70      CONTINUE

        CHK       = LAI(S) - TOTAL
        CHKLAI(S) = 100 * CHK / LAI(S)

        IF (ABS(CHKLAI(S)) .GT. 1.E-4) WRITE(*,*)' WARNING :',
     $  ' a CHKLAI is greater than 0.0001 % (see CHECK.OUT) !!'

80    CONTINUE

      RETURN
      END
```

```
*------------------------------------------------------------------*
* Subprogram : ABSRAD                                              *
*                                                                  *
* Purpose    : The subprogram ABSRAD uses the vertical distribution *
*              of the leaf area index and the daily total of global *
*              radiation to calculate the amount of radiation,     *
*              absorbed by each species (RADABS).                  *
*------------------------------------------------------------------*

      SUBROUTINE ABSRAD (NS,NL,RADGLB,EXTCF,LAILAY,REFLCF,RADABS,
     $                   RADPER,CHKRAD)

      IMPLICIT REAL (A-Z)
      INTEGER S,NS,L,NL

      DIMENSION EXTCF(NS),LAILAY(NS,NL),LAISUM(5),RAD(6),RADSUM(5),
     $          RADLAY(4,5),RADABS(NS),RADPER(NS)

*-----Only half of the global irradiance is photosynthetically active
*     and part of it is reflected.

      RAD(1) = RADGLB * 0.5 * (1. - REFLCF)

      DO 30 L=1,NL

*-----The leaf area index, per species and per layer, is multiplied
*     with the extinction coefficient (EXTCF) and summed over all
*     species (LAISUM).

        LAISUM(L) = 0.

        DO 10 S=1,NS

          LAISUM(L) = LAISUM(L) + LAILAY(S,L)*EXTCF(S)

10      CONTINUE

*-----The difference between incoming (RAD(L)) and transmitted
*     (RAD(L+1)) radiation  equals the amount of absorbed
*     radiation in a layer, summed over all species (RADSUM).

        RAD(L+1)  = RAD(L) * EXP(-LAISUM(L))
        RADSUM(L) = RAD(L) - RAD(L+1)

*-----The total amount of absorbed radiation in a layer (RADSUM)
*     is distributed among the competing species, according to
*     their share in the extinction of radiation.

        DO 20 S=1,NS

          IF (LAISUM(L) .GT. 0.) THEN
            RADLAY(S,L) = RADSUM(L) * LAILAY(S,L)*EXTCF(S)/LAISUM(L)
          ELSE
            RADLAY(S,L) = 0.
          ENDIF
```

```
20        CONTINUE

30      CONTINUE

*-----The radiation, absorbed per species and per layer (RADLAY), is
*       summed over all layers to determine the total amount of radiation,
*       absorbed by a species (RADABS).

        DO 50 S=1,NS

          RADABS(S) = 0.

          DO 40 L=1,NL

            RADABS(S) = RADABS(S) + RADLAY(S,L)

40        CONTINUE

50      CONTINUE


*-----The amount of absorbed radiation per species (RADABS) is also
*       expressed as a percentage (RADPER).

        DO 60 S=1,NS

          RADPER(S) = 100 * RADABS(S) / SUM(RADABS,NS)

60      CONTINUE


*-----The distribution of radiation among the species is checked
*       by taking the difference between the amount of radiation,
*       absorbed by all species (TOTAL) and the sum of the radiation,
*       absorbed per species.
*       CHKRAD is expressed as a percentage.
*       RAD(1) is the radiation which enters the top layer ;
*       RAD(NL+1) is the radiation at ground surface.

        TOTAL  = RAD(1) - RAD(NL+1)
        CHK    = TOTAL - SUM (RADABS,NS)
        CHKRAD = 100 * CHK / TOTAL

        IF (ABS(CHKRAD) .GT. 1.E-4) WRITE(*,*)' WARNING :',
       $' the CHKRAD is greater than 0.0001 % (see CHECK.OUT) !!'

        RETURN
        END
```

```
*-------------------------------------------------------------------*
* Subprogram : DRYMAT                                               *
*                                                                   *
* Purpose    : The subprogram DRYMAT calculates the rate of dry matter *
*              production and the net flows of dry matter into the    *
*              various plant parts through allocation and loss.       *
*-------------------------------------------------------------------*

      SUBROUTINE DRYMAT (NS,ANSW1,TIME,DELT,NDWTOT,WTOTTB,RDMP,
     $                   NDCNMX,CNLVXT,FOPMX,CNLVMN,CNLV,REDN,RADABS,
     $                   EDMP,NDFADM,FAMRTT,FAMLVT,FAMSTT,FAMERT,
     $                   WRT,RDRRT,RDMLRT,WLV,RDRLV,RDMLLV,
     $                   NFDMRT,NFDMLV,NFDMST,NFDMER)


      IMPLICIT REAL (A-Z)
      INTEGER S,NS,NDFADM,NDWTOT,NDCNMX
      CHARACTER ANSW1*1

      DIMENSION WTOTTB(NS,NDWTOT),RDMP(NS),CNLVXT(NS,NDCNMX),
     $          CNLV(NS),REDN(NS),RADABS(NS),EDMP(NS),
     $          FADMRT(4),FADMLV(4),FADMST(4),FADMER(4),
     $          FAMRTT(NS,NDFADM),FAMLVT(NS,NDFADM),
     $          FAMSTT(NS,NDFADM),FAMERT(NS,NDFADM),
     $          RDMART(4),RDMALV(4),RDMAST(4),RDMAER(4),
     $          RDRRT(NS),WRT(NS),RDMLRT(NS),
     $          RDRLV(NS),WLV(NS),RDMLLV(NS),
     $          NFDMRT(NS),NFDMLV(NS),NFDMST(NS),NFDMER(NS)


      DO 10 S=1,NS

*-----ANSW1 refers to the question whether the rate of dry matter
*     production should be a forcing variable.

        IF (ANSW1 .EQ. 'Y' .OR. ANSW1 .EQ. 'y') THEN
           WTOT1  = LINT (S,NS,NDWTOT,WTOTTB,TIME)
           WTOT2  = LINT (S,NS,NDWTOT,WTOTTB,TIME+DELT)
          RDMP(S) = WTOT2 - WTOT1
        ELSE

*-----The rate of dry matter production (RDMP) is calculated by
*     multiplying the amount of absorbed radiation (RADABS) with an
*     efficiency coefficient. This efficiency coefficient equals the
*     product of a maximum efficiency (EDMP) and a reduction factor
*     (REDN), which is a linear function of the actual nitrogen
*     concentration in live leaves (CNLV).
*     The two parameters of this function are :
*     1. a minimum concentration (CNLVMN), below which the actual
*     efficiency equals zero.
*     2. an optimum concentration (CNLVOP), above which the actual
*     efficiency has reached its maximum value. FOPMX is a factor,
*     which relates the optimum concentration for dry matter production
*     to the maximum concentration, found in leaves (CNLVMX).
```

```
          CNLVMX = LINT (1,NS,NDCNMX,CNLVXT,TIME)
          CNLVOP = FOPMX * CNLVMX

          REDN(S) = (CNLV(S) - CNLVMN) / (CNLVOP - CNLVMN)
          IF (CNLV(S) .LT. CNLVMN) REDN(S) = 0.
          IF (CNLV(S) .GT. CNLVOP) REDN(S) = 1.

          RDMP(S) = RADABS(S) * EDMP(S) * REDN(S) * 1.E+4
        ENDIF

*-----The allocation factors are calculated by linear interpolation
*     of harvest data.

        FADMRT(S) = LINT(S,NS,NDFADM,FAMRTT,TIME)
        FADMLV(S) = LINT(S,NS,NDFADM,FAMLVT,TIME)
        FADMST(S) = LINT(S,NS,NDFADM,FAMSTT,TIME)
        FADMER(S) = LINT(S,NS,NDFADM,FAMERT,TIME)


*-----The rate of dry matter production (RDMP) is distributed to
*     all plant organs, using the allocation factors.

        RDMART(S) = FADMRT(S) * RDMP(S)
        RDMALV(S) = FADMLV(S) * RDMP(S)
        RDMAST(S) = FADMST(S) * RDMP(S)
        RDMAER(S) = FADMER(S) * RDMP(S)


*-----The loss of dry matter through death of roots and leaves is
*     calculated by multiplying their dry weights (WRT ; WLV) with a
*     constant relative death rate (RDRRT ; RDRLV).

        RDMLRT(S) = RDRRT(S) * WRT(S)
        RDMLLV(S) = RDRLV(S) * WLV(S)


*-----The net flows are calculated by taking the result of allocation
*     and loss rates of dry matter.

        NFDMRT(S) = RDMART(S) - RDMLRT(S)
        NFDMLV(S) = RDMALV(S) - RDMLLV(S)
        NFDMST(S) = RDMAST(S)
        NFDMER(S) = RDMAER(S)
```

```
*-----The sum of the allocation factors should equal one.

        FADM = FADMRT(S) + FADMLV(S) + FADMST(S) + FADMER(S)

        IF ((FADM .LT. 1.) .OR. (FADM .GT. 1.)) THEN
          WRITE (*,'(A/A/F5.0,I3,5(F6.2))')
     $     ' The sum of the allocation factors used in the dry matter',
     $     ' distribution is not equal to one.',
     $     TIME,S,FADMRT(S),FADMLV(S),FADMST(S),FADMER(S),FADM
        ENDIF

10    CONTINUE

      RETURN
      END
```

```
*----------------------------------------------------------------------*
* Subprogram : NITDEM                                                  *
*                                                                      *
* Purpose    : The subprogram NITDEM calculates the demand for         *
*              nitrogen of live biomass of each species.               *
*----------------------------------------------------------------------*

      SUBROUTINE NITDEM (NS,TIME,DELT,
     $                   NDCNMX,CNRTXT,CNLVXT,CNSTXT,CNERXT,
     $                   WRT,WLV,WST,WER,
     $                   NFDMRT,NFDMLV,NFDMST,NFDMER,
     $                   ANRTMX,ANLVMX,ANSTMX,ANERMX,ANLBMX,
     $                   RDMLRT,CNDRT,RNLRT,RDMLLV,CNDLV,RNLLV,
     $                   ANLB,RNDLB)

      IMPLICIT REAL (A-Z)
      INTEGER S,NS,NDCNMX

      DIMENSION CNRTXT(NS,NDCNMX),CNLVXT(NS,NDCNMX),CNSTXT(NS,NDCNMX),
     $          CNERXT(NS,NDCNMX),
     $          WRT(NS),WLV(NS),WST(NS),WER(NS),
     $          NFDMRT(NS),NFDMLV(NS),NFDMST(NS),NFDMER(NS),
     $          ANRTMX(NS),ANLVMX(NS),ANSTMX(NS),ANERMX(NS),ANLBMX(NS),
     $          RDMLRT(NS),CNDRT(NS),RNLRT(NS),
     $          RDMLLV(NS),CNDLV(NS),RNLLV(NS),
     $          ANLB(NS),RNDLB(NS)


*-----Maximum concentrations of nitrogen in each plant organ are
*     determined by linear interpolation of data, which have been
*     derived from literature.

      CNRTMX = LINT (1,NS,NDCNMX,CNRTXT,TIME)
      CNLVMX = LINT (1,NS,NDCNMX,CNLVXT,TIME)
      CNSTMX = LINT (1,NS,NDCNMX,CNSTXT,TIME)
      CNERMX = LINT (1,NS,NDCNMX,CNERXT,TIME)

      DO 10 S=1,NS

*-----Each plant organ can contain a maximum amount of nitrogen,
*     (AN..MX), which is calculated by multiplying the maximum
*     concentration with its new biomass.

        ANRTMX(S) = (WRT(S) + NFDMRT(S) * DELT) * CNRTMX
        ANLVMX(S) = (WLV(S) + NFDMLV(S) * DELT) * CNLVMX
        ANSTMX(S) = (WST(S) + NFDMST(S) * DELT) * CNSTMX
        ANERMX(S) = (WER(S) + NFDMER(S) * DELT) * CNERMX

        ANLBMX(S) = ANRTMX(S) + ANLVMX(S) + ANSTMX(S) + ANERMX(S)
```

```
*-----The rates of nitrogen loss through death of roots and leaves
*     (RNLRT ; RNLLV) are determined by the product of the rates of
*     dry matter loss (RDMLRT ; RDMLLV) and the concentrations of
*     nitrogen in dead roots cq. leaves (CNDRT ; CNDLV).

        RNLRT(S) = RDMLRT(S) * CNDRT(S)
        RNLLV(S) = RDMLLV(S) * CNDLV(S)

*-----The difference between the maximum amount (ANLBMX) and the actual
*     amount (ANLB), divided by DELT, plus the losses of nitrogen
*     (RNLRT + RNLLV) is called the rate of nitrogen demand (RNDLB).
*     If this amount is taken up, then the species will reach the
*     maximum nitrogen concentrations in all plant organs.

        RNDLB(S) = (ANLBMX(S) - ANLB(S))/DELT + RNLRT(S) + RNLLV(S)

*-----A negative rate means that the actual nitrogen concentration
*     will exceed the maximum concentration and therefore the losses of
*     nitrogen (RNLRT ; RNLLV) are raised with this excess (ABS(RNDLB))
*     The demand is set to zero, which means that no nitrogen will
*     be taken up from the soil.

        IF (RNDLB(S) .LT. 0.) THEN
          RNLTOT   = RNLRT(S) + RNLLV(S)
          RNLRT(S) = RNLRT(S) + ABS(RNDLB(S)) * RNLRT(S)/RNLTOT
          RNLLV(S) = RNLLV(S) + ABS(RNDLB(S)) * RNLLV(S)/RNLTOT

          RNDLB(S) = 0.
        ENDIF

10    CONTINUE

      RETURN
      END
```

```
*-----------------------------------------------------------------*
* Subprogram : NITDIS                                             *
*                                                                 *
* Purpose    : The subprogram NITDIS calculates the rate of nitrogen *
*              supply in the soil and the rates of nitrogen uptake  *
*              of each species.                                    *
*              It also determines the net flows of nitrogen into live *
*              and dead biomass and the allocation factors of      *
*              nitrogen to the various plant organs.               *
*-----------------------------------------------------------------*

      SUBROUTINE NITDIS (NS,TIME,DELT,RNSM,ANSL,
     $                   RNDLB,RLI,RNU,RNUPER,
     $                   ANRTMX,ANLVMX,ANSTMX,ANERMX,ANLBMX,
     $                   FANRT,FANLV,FANST,FANER,
     $                   RNLRT,RNLLV,NFNLB,NFNDB)


      IMPLICIT REAL (A-Z)
      INTEGER S,NS

      DIMENSION RNDLB(NS),NDEF(4),RLI(NS),RNU(NS),RNUPER(NS),
     $          ANRTMX(NS),ANLVMX(NS),ANSTMX(NS),ANERMX(NS),ANLBMX(NS),
     $          FANRT(NS),FANLV(NS),FANST(NS),FANER(NS),
     $          RNLRT(NS),RNLLV(NS),NFNLB(NS),NFNDB(NS)


*-----The rate of nitrogen supply (RNS) equals the amount of available
*     nitrogen in the soil (ANSL), divided by DELT.

      IF (TIME .EQ. 1.) ANSL = RNSM * DELT
      RNS = ANSL / DELT


*-----The rate of nitrogen uptake (RNU) is calculated by distributing
*     the rate of nitrogen supply (RNS) among the competing species.


*-----The initial value of the rate of nitrogen uptake equals  zero.
*     The amount of nitrogen, which is initially needed to satisfy
*     the demand (nitrogen deficiency : NDEF), equals the rate of
*     nitrogen demand of live biomass (RNDLB).

      DO 10 S=1,NS

        RNU(S)  = 0.
        NDEF(S) = RNDLB(S)

10    CONTINUE
```

```
*-----Only a species, which has a nitrogen deficiency (NDEF > 0),
*     will take up a certain amount of nitrogen in proportion to
*     its share in the sum of the root length indices of all species
*     (RLISUM) with a nitrogen deficiency.

15    RLISUM = 0.

      DO 20 S=1,NS

        IF (NDEF(S) .GT. 0.) THEN
          RLISUM = RLISUM + RLI(S)
        ENDIF

20    CONTINUE

*-----The rate of nitrogen uptake can not exceed the rate of nitrogen
*     demand of live biomass (RNDLB).

      DO 30 S=1,NS

        IF (NDEF(S) .GT. 0.) THEN
          RNU(S)  = RNU(S) + RNS * RLI(S) / RLISUM
          IF (RNU(S) .GT. RNDLB(S)) RNU(S) = RNDLB(S)
          NDEF(S) = RNDLB(S) - RNU(S)
        ENDIF

30    CONTINUE

*-----The initial rate of nitrogen supply (ANSL/DELT) decreases
*     with the rate of nitrogen uptake, summed over all species.

      RNS = (ANSL / DELT) - SUM(RNU,NS)

*-----If there is still some nitrogen left (RNS > 0) and if at
*     least one of the species has not yet satisfied its demand
*     (SUM(NDEF,NS) > 0), the nitrogen, which is still available
*     (RNS), is distributed again among the unsatisfied species
*     (GOTO 15).
*     These distribution calculations will continue until all nitrogen
*     is taken up (RNS = 0) or each species has satisfied its demand
*     (SUM(NDEF,NS) = 0).

      IF (RNS .GT. 0. .AND. SUM(NDEF,NS) .GT. 0.) GOTO 15


*-----The rate of nitrogen uptake is also calculated as a percentage
*     (RNUPER).

      DO 40 S=1,NS

        RNUPER(S) = 100 * RNU(S) / (SUM(RNU,NS) + 1.E-20)

40    CONTINUE
```

```
      DO 50 S=1,NS

*-----The net flows of nitrogen into live and dead biomass (NFNLB ;
*     NFNDB) are calculated by taking the result of the uptake and
*     the loss rates.

        NFNLB(S) = RNU(S) - RNLRT(S) - RNLLV(S)
        NFNDB(S) = RNLRT(S) + RNLLV(S)


*-----The factors of allocation of nitrogen towards the various
*     plant organs are determined by their share in the maximum
*     amount of nitrogen, that the live biomass of a species could
*     contain.

        FANRT(S) = ANRTMX(S) / ANLBMX(S)
        FANLV(S) = ANLVMX(S) / ANLBMX(S)
        FANST(S) = ANSTMX(S) / ANLBMX(S)
        FANER(S) = ANERMX(S) / ANLBMX(S)


50    CONTINUE

      RETURN
      END
```

```
*----------------------------------------------------------------------*
* Subprogram  : OUTPUT                                                 *
*                                                                      *
* Purpose     : The subprogram OUTPUT writes the results of the        *
*               calculations to output files, seperately for each      *
*               species (extension : .OUT).                            *
*               It also creates the file CHECK.OUT. The variables in   *
*               this file have been calculated to check the            *
*               computations.                                          *
*----------------------------------------------------------------------*

      SUBROUTINE OUTPUT (NS,TIME,FINTIM,FLNAME,TITLE,
     $                   DAY,LAI,HGT,RADABS,RADPER,
     $                   WRT,WLV,WST,WER,WDRT,WDLV,WLB,WTOT,
     $                   ANSL,RLI,RNU,RNUPER,CNRT,CNLV,REDN,ANLB,ANDB,
     $                   CHKLAI,CHKRAD,CHKWTT,CHKNIT)

      IMPLICIT REAL (A-Z)
      INTEGER S,NS,FLNUM1,FLNUM2,FLNUM3,DAY
      CHARACTER FLNAME*6,TITLE*60,REMARK*15

      DIMENSION FLNAME(NS),TITLE(NS),RADABS(NS),RADPER(NS),
     $          WRT(NS),WLV(NS),WST(NS),WER(NS),WDRT(NS),WDLV(NS),
     $          WSH(4),WLB(NS),WTOT(NS),
     $          HGT(NS),LAI(NS),RLI(NS),RNU(NS),RNUPER(NS),ANLB(NS),
     $          CNRT(NS),CNLV(NS),REDN(NS),ANDB(NS),
     $          CHKLAI(NS),CHKWTT(NS)


*-----Initialisation of the subroutine by opening three files with
*     the names (FLNAME)R.OUT ,(FLNAME)N.OUT and (FLNAME)W.OUT.
*     Each file needs its own specific filenumber (FLNUM1 ; FLNUM2 ;
*     FLNUM3).

      IF (NS .EQ. 1) REMARK = ' Mono culture.'
      IF (NS .GT. 1) REMARK = ' Mixed culture.'

      DO 10 S=1,NS

        FLNUM1 = 20 + S
        FLNUM2 = 40 + S
        FLNUM3 = 50 + S

        IF (TIME .EQ. 1.) THEN
          OPEN (UNIT=FLNUM1,FILE=FLNAME(S) // 'R.OUT',STATUS='NEW')
          WRITE (FLNUM1,'(A/A/,/A/A)')
     $    TITLE(S),
     $    REMARK,
     $    ' TIME  DAY  RADABS  RADPER   HGT   LAI ',
     $    '  (d)  (-)(J/cm2.d)    (%)  (cm)   (-) '
```

```
        OPEN (UNIT=FLNUM2,FILE=FLNAME(S) // 'N.OUT',STATUS='NEW')
        WRITE (FLNUM2,'(A/A/,/A,A/A,A)')
     $    TITLE(S),
     $    REMARK,
     $    ' TIME    ANSL     RLI      RNU  RNUPER    CNRT     CNLV',
     $    '    REDN     ANLB     ANDB ',
     $    '  (d)  (g/m2)  (m/m2) (g/m2.d)    (%)    (g/g)    (g/g)',
     $    '       (-)  (g/m2)  (g/m2)'

        OPEN (UNIT=FLNUM3,FILE=FLNAME(S) // 'W.OUT',STATUS='NEW')
        WRITE (FLNUM3,'(A/A/A/,/A,A)')
     $    TITLE(S),
     $    REMARK,
     $    ' All weights are expressed in g DM/m2.',
     $    ' TIME     WRT     WLV     WST     WER',
     $    '    WDRT    WDLV     WSH     WLB    WTOT '
      ENDIF

*-----The results are written to the output files.

      WRITE (FLNUM1,'(F5.0,I5,2(F8.0),F6.1,F6.2)')TIME,DAY,
     $                                  RADABS(S),RADPER(S),
     $                                  HGT(S),LAI(S)

      WRITE (FLNUM2,'(F5.0,F8.3,F8.0,F8.3,F8.0,5(F8.3))')TIME,ANSL,
     $                                RLI(S),RNU(S),RNUPER(S),CNRT(S),
     $                                CNLV(S),REDN(S),ANLB(S),ANDB(S)

      WSH(S) = WLV(S)+WST(S)+WER(S)
      WRITE (FLNUM3,'(F5.0,9(F8.1))')TIME,WRT(S),WLV(S),WST(S),
     $                                  WER(S),WDRT(S),WDLV(S),
     $                                  WSH(S),WLB(S),WTOT(S)

*-----The output files are closed again when TIME equals FINTIM.

      IF (TIME .EQ. FINTIM) THEN
        CLOSE (FLNUM1)
        CLOSE (FLNUM2)
        CLOSE (FLNUM3)
      ENDIF

10    CONTINUE
```

```
*-----The file CHECK.OUT is created only once for all species.

      IF (TIME .EQ. 1.) THEN
        OPEN (UNIT=20,FILE='CHECK.OUT',STATUS='NEW')
        WRITE (20,'(A/,/,5(A/))')
     $  ' This file contains the check variables of all species.',
     $  ' First column  : TIME',
     $  '    NS columns : CHKLAI(1) .... CHKLAI(NS)',
     $  '   one column  : CHKRAD',
     $  '    NS columns : CHKWTT(1) .... CHKWTT(NS)',
     $  '   one column  : CHKNIT'
      ENDIF

      WRITE (20,'(F5.0,6(E10.1))') TIME,(CHKLAI(S),S=1,NS),CHKRAD,
     $                             (CHKWTT(S),S=1,NS),CHKNIT

      IF (TIME .EQ. FINTIM) THEN
        CLOSE (20)
      ENDIF

      RETURN
      END
```

```
*-----------------------------------------------------------------------*
* Subprogram : INTGRT                                                   *
*                                                                       *
* Purpose    : The subprogram INTGRT integrates all state variables     *
*              in time.                                                 *
*-----------------------------------------------------------------------*

      SUBROUTINE INTGRT (NS,ND,TIME,DELT,ANSW2,RDMP,
     $                   NFDMRT,NFDMLV,NFDMST,NFDMER,RDMLRT,RDMLLV,
     $                   WTOT,WRT,WLV,WST,WER,WDRT,WDLV,WLB,WDB,CHKWTT,
     $                   SRL,FRTN,RLI,NDLAI,LAITB,NDSLA,SLATB,LAI,
     $                   ANLB,ANRT,ANLV,ANST,ANER,ANDB,
     $                   NFNLB,NFNDB,FANRT,FANLV,FANST,FANER,
     $                   CNRT,CNLV,CNST,CNER,
     $                   NGDATE,NGIFT,NRECOV,RNU,ANSL,RNSM,CHKNIT)

      IMPLICIT REAL (A-Z)
      INTEGER S,NS,ND,NDLAI,NDSLA
      CHARACTER ANSW2*1

      DIMENSION RDMP(NS),NFDMRT(NS),NFDMLV(NS),NFDMST(NS),NFDMER(NS),
     $          WTOT(NS),WRT(NS),WLV(NS),WST(NS),WER(NS),
     $          RDMLRT(NS),RDMLLV(NS),WDRT(NS),WDLV(NS),WLB(NS),WDB(NS),
     $          SRL(NS),RLI(NS),
     $          NDLAI(NS),LAITB(NS,ND),SLATB(NS,NDSLA),SLA(4),LAI(NS),
     $          CHKWTT(NS),
     $          NFNLB(NS),ANLB(NS),NFNDB(NS),ANDB(NS),
     $          FANRT(NS),FANLV(NS),FANST(NS),FANER(NS),
     $          ANRT(NS),ANLV(NS),ANST(NS),ANER(NS),
     $          CNRT(NS),CNLV(NS),CNST(NS),CNER(NS),RNU(NS)

      DO 10 S=1,NS

*-----Integration of dry matter.

        WTOT(S) = WTOT(S) +   RDMP(S) * DELT

        WRT(S)  =  WRT(S) + NFDMRT(S) * DELT
        WLV(S)  =  WLV(S) + NFDMLV(S) * DELT
        WST(S)  =  WST(S) + NFDMST(S) * DELT
        WER(S)  =  WER(S) + NFDMER(S) * DELT

        WDRT(S) = WDRT(S) + RDMLRT(S) * DELT
        WDLV(S) = WDLV(S) + RDMLLV(S) * DELT

        WLB(S)  =  WRT(S) +  WLV(S) + WST(S) + WER(S)
        WDB(S)  = WDRT(S) + WDLV(S)
```

```
*-----CHKWTT is calculated to check the dry matter distribution
*     over the various plant parts.

        CHK       = WTOT(S) - (WLB(S) + WDB(S))
        CHKWTT(S) = 100 * CHK / WTOT(S)

        IF (ABS(CHKWTT(S)) .GT. 1.E-4) WRITE(*,*)' WARNING :',
     $  ' a CHKWTT is greater than 0.0001 % (see CHECK.OUT) !!'


*-----Calculation of the root length index by the product of the root
*     biomass with the specific root length. Part of the root biomass
*     (FRTN) is not contributing to the root length index.

        RLI(S) = WRT(S) * (1. - FRTN) * SRL(S)

*-----Calculation of the leaf area index.
*     ANSW2 refers to the question whether the leaf area index should
*     be a forcing variable.

        IF (ANSW2 .EQ. 'Y' .OR. ANSW2 .EQ. 'y') THEN
          LAI(S) = LINT (S,NS,NDLAI(S),LAITB,TIME+DELT)
        ELSE
          SLA(S) = LINT (S,NS,NDSLA,SLATB,TIME+DELT)
          LAI(S) = WLV(S) * SLA(S)
        ENDIF


*-----The initial amount of nitrogen in biomass (ANLBIN) is needed to
*     calculate CHKNIT.

        IF (TIME .EQ. 1. .AND. S .EQ. 1) ANLBIN = SUM(ANLB,NS) +
     $                                            SUM(ANDB,NS)

*-----Integration of the amounts of nitrogen and calculation of
*     nitrogen concentrations.

        ANLB(S) = ANLB(S) + NFNLB(S) * DELT

        ANRT(S) = FANRT(S) * ANLB(S)
        ANLV(S) = FANLV(S) * ANLB(S)
        ANST(S) = FANST(S) * ANLB(S)
        ANER(S) = FANER(S) * ANLB(S)

        ANDB(S) = ANDB(S) + NFNDB(S) * DELT

        CNRT(S) = ANRT(S) / WRT(S)
        CNLV(S) = ANLV(S) / WLV(S)
        CNST(S) = ANST(S) / WST(S)
        CNER(S) = ANER(S) / (WER(S)+1.E-20)

10    CONTINUE
```

```
*-----Integration of the amount of available nitrogen in the soil
*     (ANSL).

      IF (TIME .EQ. NGDATE) THEN
        RNSF = (NRECOV * NGIFT) / DELT
      ELSE
        RNSF = 0.
      ENDIF

      ANSL = ANSL + (RNSM + RNSF - SUM(RNU,NS)) * DELT


*-----The total nitrogen balance is checked.

      IF (TIME .EQ. 1.) ANMTOT = RNSM * DELT
      ANMTOT = ANMTOT + RNSM * DELT

*-----The amount of nitrogen, which is present in the entire plant-
*     soil system (ANTBSL), equals the sum of the initial amount in
*     the biomass of the species (ANLBIN), the total amount of nitrogen
*     released by mineralisation (ANMTOT) and the initial amount of
*     available fertilizer nitrogen (NRECOV*NGIFT).

      IF (TIME .LT. NGDATE) THEN
        ANTBSL = ANLBIN + ANMTOT
      ELSE
        ANTBSL = ANLBIN + ANMTOT + NRECOV*NGIFT
      ENDIF

*-----ANTBSL should be equal to the amount of nitrogen, which is present
*     in live and dead biomass (ANTB) plus the amount, which is left
*     available in the soil (ANSL).

      ANTB = SUM(ANRT,NS) + SUM(ANLV,NS) + SUM(ANST,NS) + SUM(ANER,NS)
     $        + SUM(ANDB,NS)
      CHK = ANTBSL - (ANTB + ANSL)
      CHKNIT = 100 * CHK / ANTBSL

      IF (ABS(CHKNIT) .GT. 1.E-4) WRITE(*,*)' WARNING :',
     $' the CHKNIT is greater than 0.0001 % (see CHECK.OUT) !!'


      RETURN
      END
```

```
*-----------------------------------------------------------------------*
* Subprogram : SUM                                                      *
*                                                                       *
* Purpose    : The subprogram SUM sums a variable (VAR) over all        *
*              species (NS).                                            *
*-----------------------------------------------------------------------*

      REAL FUNCTION SUM (VAR,NS)

      IMPLICIT REAL (A-Z)
      INTEGER S,NS

      DIMENSION VAR(NS)

*-----Initialisation of SUM.

      SUM=0.

*-----A variable (VAR) is summed over all species.

      DO 10 S=1,NS

        SUM = SUM + VAR(S)

10    CONTINUE

      RETURN
      END
```

```
*-----------------------------------------------------------------------*
* Subprogram : LINT                                                     *
*                                                                       *
* Purpose    : The subprogram LINT calculates the Y-value at a given   *
*              X-value by linear interpolation of data points.          *
*              DATATB is a table of X-data with corresponding Y-data:  *
*              X1,Y1,X2,Y2,....Xn,Yn (n+n = ND), one for each species.*
*-----------------------------------------------------------------------*

      REAL FUNCTION LINT(S,NS,ND,DATATB,X)

      IMPLICIT REAL (A-Z)
      INTEGER S,NS,D,ND,HELP

      DIMENSION DATATB(NS,ND)

*-----X-data should be placed in ascending order !

*-----The first two IF-statements refer to the situation that the X-
*     value lies beyond the defined X-data range. In that case the Y-
*     value equals the nearest Y-data.

      IF (X .LE. DATATB(S,1))     Y = DATATB(S,2)
      IF (X .GE. DATATB(S,ND-1))  Y = DATATB(S,ND)

      IF (X .GT. DATATB(S,1) .AND. X .LT. DATATB(S,ND-1)) THEN
        HELP = 0
        DO 10 D=3,ND,2

*-----If HELP equals 1, then the slope and the Y-value have already
*     been calculated.

          IF (X .LE. DATATB(S,D) .AND. HELP .EQ. 0) THEN
            SLOPE = (DATATB(S,D+1) - DATATB(S,D-1)) /
     $              (DATATB(S,D)   - DATATB(S,D-2))
            Y     = DATATB(S,D-1) + SLOPE * (X - DATATB(S,D-2))
            HELP  = 1
          ENDIF

10      CONTINUE
      ENDIF

      LINT = Y

      RETURN
      END
```

Appendix III

List of Symbols

Abbrev.	Meaning	Unit
	------------------------------- A -------------------------------	
ANER	Amount of Nitrogen in EaRs	g/m^2
ANERMX	Amount of Nitrogen in EaRs (MaXimum)	g/m^2
ANDB	Amount of Nitrogen in Dead Biomass	g/m^2
ANLB	Amount of Nitrogen in Live Biomass	g/m^2
ANLBIN	Amount of Nitrogen in Live Biomass (INitial)	g/m^2
ANLBMX	Amount of Nitrogen in Live Biomass (MaXimum)	g/m^2
ANLV	Amount of Nitrogen in LeaVes	g/m^2
ANLVMX	Amount of Nitrogen in LeaVes (MaXimum)	g/m^2
ANMTOT	Amount of Nitrogen, released by Mineralisation (TOTal)	g/m^2
ANRT	Amount of Nitrogen in RooTs	g/m^2
ANRTMX	Amount of Nitrogen in RooTs (MaXimum)	g/m^2
ANSL	Amount of available Nitrogen in the SoiL	g/m^2
ANST	Amount of Nitrogen in STems	g/m^2
ANSTMX	Amount of Nitrogen in STems (MaXimum)	g/m^2
ANTB	Amount of Nitrogen in Total Biomass	g/m^2
ANTBSL	Amount of Nitrogen in Total Biomass and SoiL	g/m^2
	------------------------------- C -------------------------------	
CHKLAI	CHecKing variable of the vertical distribution of Leaf Area Index	-
CHKNIT	CHecKing variable of the distribution of NITrogen among the soil and the live and dead biomass of the competing species	-
CHKRAD	CHecKing variable of the distribution of absorbed RADiation among the competing species	-
CHKWTT	CHecKing variable of the dry matter distribution among the various plant parts per species	-
CNDLV	Concentration of Nitrogen in Dead LeaVes	g N/g DM
CNDRT	Concentration of Nitrogen in Dead RooTs	g N/g DM
CNER	Concentration of Nitrogen in EaRs	g N/g DM
CNERMX	Concentration of Nitrogen in EaRs (MaXimum)	g N/g DM
CNERXT	Table of CNERMX and TIME	
CNLV	Concentration of Nitrogen in LeaVes	g N/g DM
CNLVMN	MiNimum Nitrogen Concentration in LeaVes (a constant, used to calculate REDN)	g N/g DM
CNLVMX	Concentration of Nitrogen in LeaVes (MaXimum)	g N/g DM
CNLVOP	OPtimum Nitrogen Concentration in Leaves (a variable, used to calculate REDN)	g N/g DM
CNLVXT	Table of CNLVMX and TIME	
CNRT	Concentration of Nitrogen in RooTs	g N/g DM
CNRTMX	Concentration of Nitrogen in RooTs (MaXimum)	g N/g DM
CNRTXT	Table of CNRTMX and TIME	

Abbrev.	Meaning	Unit
CNST	Concentration of Nitrogen in STems	g N/g DM
CNSTMX	Concentration of Nitrogen in STems (MaXimum)	g N/g DM
CNSTXT	Table of CNSTMX and TIME	

------------------------------- D -------------------------------

D	Data number	-
DAY	DAY number in a Julian calendar	-
DELT	Time step of integration	d

------------------------------- E -------------------------------

EXTCF	EXTinction CoeFficient	-
EDMP	Efficiency of Dry Matter Production (maximum)	g DM/J

------------------------------- F -------------------------------

FADMER	Factor of Allocation of Dry Matter to EaRs	-
FADMLV	Factor of Allocation of Dry Matter to LeaVes	-
FADMRT	Factor of Allocation of Dry Matter to RooTs	-
FADMST	Factor of Allocation of Dry Matter to STems	-
FAMERT	Table of FADMER and TIME	
FAMLVT	Table of FADMLV and TIME	
FAMRTT	Table of FADMRT and TIME	
FAMSTT	Table of FADMST and TIME	
FANER	Factor of Allocation of Nitrogen to EaRs	-
FANLV	Factor of Allocation of Nitrogen to LeaVes	-
FANRT	Factor of Allocation of Nitrogen to RooTs	-
FANST	Factor of Allocation of Nitrogen to STems	-
FINTIM	simulation period	d
FOPMX	Factor relating the OPtimum to the MaXimum nitrogen concentration	-
FRTN	Fraction of the RooT biomass, which is present as a stump	-

------------------------------- H -------------------------------

HGT	HeiGhT of a species	cm
HGTLAY	HeiGhT of a horizontal LAYer (upper boundary)	cm
HGTREL	HeiGhT, above ground surface, relative to the height of a species	-
HGTTB	TaBle of HGT and TIME	

Abbrev.	Meaning	Unit
	L	
L	Layer number	-
LAI	Leaf Area Index of a species	m^2/m^2
LAILAY	Leaf Area Index of a species in a LAYer	m^2/m^2
LAIREL	Leaf Area Index beneath a certain height, RELative to the total leaf area index (LAI) of a species	-
LAISUM	product of Leaf Area Index and extinction coefficient per layer, SUMmed over all species	m^2/m^2
LAITB	TaBle of LAI and TIME	
	N	
ND	Number of Data of the tables (maximum)	-
NDCNMX	Number of Data of the table, containing the MaXimum Nitrogen Concentrations	-
NDEF	Nitrogen DEFiciency	$g/m^2.d^{NB}$
NDFADM	Number of Data of the table, containing the Allocation Factors of Dry Matter	-
NDHGT	Number of Data of the table, containing the HeiGhts of a species	-
NDLAI	Number of Data of the table, containing the Leaf Area Indices	-
NDSLA	Number of Data of the table, containing the Specific Leaf Areas	-
NDVDLV	Number of Data of the table, containing the parameter V of the Vertical Distribution function of the Leaf area index (VDLV)	-
NDWTOT	Number of Data of the table, containing the dry Weights of TOTal biomass	-
NFDMER	Net Flow of Dry Matter to EaRs	$g/m^2.d$
NFDMLV	Net Flow of Dry Matter to LeaVes	$g/m^2.d$
NFDMRT	Net Flow of Dry Matter to RooTs	$g/m^2.d$
NFDMST	Net Flow of Dry Matter to STems	$g/m^2.d$
NFNDB	Net Flow of Nitrogen to Dead Biomass	$g/m^2.d$
NFNLB	Net Flow of Nitrogen to Live Biomass	$g/m^2.d$
NGDATE	DATE of Nitrogen Gift	d
NGIFT	Nitrogen Gift	g/m^2
NL	Number of horizontal Layers	-
NRECOV	RECOVery factor of Nitrogen from fertilization	-
NS	Number of competing Species	-

NB : In this report the expressions $J/cm^2.d$ and $g/m^2.d$ are used for $J\ cm^{-2}\ d^{-1}$ and $g\ m^{-2}\ d^{-1}$ respectively.

Abbrev.	Meaning	Unit
	R	
RAD(L)	amount of RADiation, entering layer L	J/cm².d
RADABS	amount of ABSorbed RADiation per species	J/cm².d
RADLAY	amount of absorbed RADiation per species per LAYer	J/cm².d
RADGLB	amount of daily total GLoBal RADiation	J/cm².d
RADPER	RADABS expressed as PERcentage of the radiation, absorbed by all species.	-
RADSUM	amount of RADiation, absorbed per layer, SUMmed over all species	J/cm².d
RANK	a number, which indicates the sequence in height of the species	-
RDMAER	Rate of Dry Matter Allocation to EaRs	g/m².d
RDMALV	Rate of Dry Matter Allocation to LeaVes	g/m².d
RDMART	Rate of Dry Matter Allocation to RooTs	g/m².d
RDMAST	Rate of Dry Matter Allocation to STems	g/m².d
RDMLLV	Rate of Dry Matter Loss through death of LeaVes	g/m².d
RDMLRT	Rate of Dry Matter Loss through death of RooTs	g/m².d
RDMP	Rate of Dry Matter Production	g/m².d
RDRLV	Relative Death Rate of LeaVes	d-1
RDRRT	Relative Death Rate of RooTs	d-1
REDN	Factor of REDuction on the dry matter production, caused by a suboptimum Nitrogen concentration	-
REFLCF	REFLection CoeFicient	-
RNS	Rate of Nitrogen Supply in the soil	g/m².d
RNSF	Rate of Nitrogen Supply by Fertilization	g/m².d
RNSM	Rate of Nitrogen Supply by Mineralization	g/m².d
RNDLB	Rate of Nitrogen Demand for Live Biomass	g/m².d
RNLLV	Rate of Nitrogen Loss through death of Leaves	g/m².d
RNLRT	Rate of Nitrogen Loss through death of RooTs	g/m².d
RNU	Rate of Nitrogen Uptake per species	g/m².d
RNUPER	RNU expressed as PERcentage of the nitrogen uptake by all species	-
RLI	Root Length Index of a species	m/m²
RLISUM	Root Length Index, SUMmed over all species with a nitrogen deficiency greater than zero	m/m²
	S	
S	Species number	-
SLA	Specific Leaf Area	m²/g DM
SLATB	TaBle of SLA and TIME	
SRL	Specific Root Length	m/g DM
	T	
TAMIN	MINimum Air Temperature	°C
TAMAX	MAXimum Air Temperature	°C
TIME	TIME	d

Abbrev.	Meaning	Unit
	------------------------------- V -------------------------------	
VDLK	parameter K of the Vertical Distribution function of the Leaf area index	-
VDLV	variable V of the Vertical Distribution function of the Leaf area index	-
VDLVTB	TaBle of VDLV and TIME	
	------------------------------- W -------------------------------	
WER	dry Weight of EaRs	g/m^2
WDB	dry Weight of Dead Biomass	g/m^2
WDLV	dry Weight of Dead LeaVes	g/m^2
WDRT	dry Weight of Dead RooTs	g/m^2
WLB	dry Weight of Live Biomass	g/m^2
WLV	dry Weight of LeaVes	g/m^2
WRT	dry Weight of RooTs	g/m^2
WSH	dry Weight of live SHoot	g/m^2
WST	dry Weight of STems	g/m^2
WTOT	dry Weight of TOTal biomass	g/m^2
WTOTTB	TaBle of WTOT and TIME	

Appendix IV

Input Files

AEF881.DAT
FRF881.DAT
WTHR88.DAT

File : AEF881.DAT

```
 Arrhenatherum elatius ; fertilized/till 1st cut ; 1988.
*Parameters, tables and initial values have been derived from
*monoculture or from literature.
*1. Specific parameters.
*    (15)     **  (10)  *  Units
EXTCF                 0.6   -
EDMP            0.0000030   g/J
RDRRT               0.010   d-1
RDRLV               0.015   d-1
CNDRT               0.005   g N/g DM
CNDLV               0.005   g N/g DM
SRL                  124.   m/g
VDLK                  8.4   -
*2. Tables.
*Table of TIME and VDLV (-)
NDVDLV                  8
  1.     0.17
 29.     0.37
 50.     0.45
 71.     0.68
*Table of TIME and HGT (cm)
NDHGT                  10
  1.      5.0
 15.     10.0
 29.     20.0
 50.     80.0
 71.     80.0
*Table of TIME and LAI (-)
NDLAI                  14
  1.     0.45
 15.     0.54
 29.     2.00
 47.     5.22
 50.     5.22
 53.     5.22
 71.     3.00
*Table of TIME and FADMRT (-)
NDFADM                 16
  1.     0.55
 14.     0.55
 15.     0.15
 28.     0.15
 29.     0.05
 49.     0.05
 50.     0.05
 71.     0.05
*Table of TIME and FADMLV (-)
NDFADM                 16
  1.     0.35
 14.     0.35
 15.     0.46
 28.     0.46
 29.     0.21
 49.     0.21
 50.     0.06
 71.     0.06
*Table of TIME and FADMST (-)
NDFADM                 16
  1.     0.10
 14.     0.10
 15.     0.39
 28.     0.39
 29.     0.68
 49.     0.68
 50.     0.75
 71.     0.75
*Table of TIME and FADMER (-)
NDFADM                 16
  1.     0.00
 14.     0.00
 15.     0.00
 28.     0.00
 29.     0.06
 49.     0.06
 50.     0.14
 71.     0.14
```

AEF881.DAT (continued)

```
*Table of TIME and SLA (m²/g)
NDSLA                    10
  1.    0.022
 15.    0.017
 29.    0.025
 50.    0.029
 71.    0.023
*Table of TIME and WTOT (g/m²)
NDWTOT                   10
  1.     273.8
 15.     372.5
 29.     440.5
 50.     945.8
 71.    1190.9
*3. Initial values of state variables.
*
WRT                 105.4   g/m²
WLV                  20.1   g/m²
WST                   7.1   g/m²
WDRT                105.4   g/m²
WDLV                 35.9   g/m²

ANRT                 1.05   g/m²
ANLV                 0.50   g/m²
ANST                 0.11   g/m²
```

*NB : The first 15 positions are used for writing the names of the parameters/variables ; the next 10 positions are used for writing the value of it.

File : FRF881.DAT

```
 Festuca rubra ; fertilized/till 1st cut ; 1988.
*Parameters, tables and initial values have been derived from
*monoculture or from literature.
*1. Specific parameters.
*    (15)     **  (10)  *  Units
EXTCF                0.5    -
EDMP           0.0000030   g/J
RDRRT              0.010   d-1
RDRLV              0.015   d-1
CNDRT              0.005   g N/g DM
CNDLV              0.005   g N/g DM
SRL                 293.   m/g
VDLK                11.8    -
*2. Tables.
*Table of TIME and VDLV (-)
NOVDLV                 8
  1.    0.17
 29.    0.17
 50.    0.24
 71.    0.24
*Table of TIME and HGT (cm)
NDHGT                 10
  1.     5.0
 15.     5.0
 29.    20.0
 50.    50.0
 71.    50.0
*Table of TIME and LAI (-)
NDLAI                 10
  1.    0.43
 15.    0.72
 29.    1.28
 50.    2.33
 71.    2.43
*Table of TIME and FADMRT (-)
NDFADM                16
  1.    0.50
 14.    0.50
 15.    0.40
 28.    0.40
 29.    0.08
 49.    0.08
 50.    0.08
 71.    0.08
*Table of TIME and FADMLV (-)
NDFADM                16
  1.    0.36
 14.    0.36
 15.    0.50
 28.    0.50
 29.    0.36
 49.    0.36
 50.    0.40
 71.    0.40
*Table of TIME and FADMST (-)
NDFADM                16
  1.    0.14
 14.    0.14
 15.    0.10
 28.    0.10
 29.    0.39
 49.    0.39
 50.    0.44
 71.    0.44
*Table of TIME and FADMER (-)
NDFADM                16
  1.    0.00
 14.    0.00
 15.    0.00
 28.    0.00
 29.    0.17
 49.    0.17
 50.    0.08
 71.    0.08
```

FRF881.DAT (continued)

```
*Table of TIME and SLA (m²/g)
NDSLA                    10
  1.   0.011
 15.   0.014
 29.   0.010
 50.   0.013
 71.   0.012
*Table of TIME and WTOT (g/m²)
NDWTOT                   10
  1.    569.4
 15.    676.5
 29.    897.7
 50.   1088.6
 71.   1345.1
*3. Initial values of state variables.
*
WRT                   212.7   g/m²
WLV                    39.1   g/m²
WST                    12.2   g/m²
WDRT                  212.7   g/m²
WDLV                   92.6   g/m²

ANRT                   2.13   g/m²
ANLV                   0.98   g/m²
ANST                   0.18   g/m²
```

*NB : The first 15 positions are used for writing the names of the parameters/variables ; the next 10 positions are used for writing the value of it.

File : WTHR88.DAT

```
*WEATHER DATA OF STATION WAGENINGEN ; 1988.
*DAY       TAMIN      TAMAX     RADGLB
*           (°C)       (°C)  (J/cm².d)
  88         6.1        9.2      546.0
  89         5.5       12.3      733.0
  90         5.6        9.1      545.0
  91         2.4       11.4     1608.0
  92         0.0       12.6     1398.0
  93         1.6       11.6     1725.0
  94         3.3       10.8     1183.0
  95         2.8        9.2      730.0
  96         2.9       12.6     1737.0
  97         4.2       15.0     1417.0
  98         4.1       10.8      794.0
  99         0.3        7.3     1287.0
 100        -0.8        9.5     1479.0
 101         5.1       13.2     1638.0
 102         3.0       13.7     1712.0
 103         0.0        9.3     1866.0
 104        -3.3       13.1     2014.0
 105         6.9       17.2     1762.0
 106        10.2       17.1      812.0
 107         5.6       16.1      938.0
 108         3.3       19.3     1732.0
 109        12.2       23.9     1615.0
 110         7.4       15.1      893.0
 111         7.1       13.0      887.0
 112         2.2       10.2     2044.0
 113         0.7        8.4     2143.0
 114        -1.5        9.7     2363.0
 115        -1.1        9.8     1803.0
 116         1.1       11.4     1680.0
 117         2.3       14.0     2125.0
 118         3.6       10.8     1471.0
 119         3.4       14.0     1165.0
 120         5.1       20.4     1750.0
 121         8.3       20.7     1680.0
 122         9.5       19.4     2038.0
 123         9.8       16.2     1309.0
 124         9.2       14.2     1149.0
 125         3.7       16.3     1555.0
 126         0.6       19.5     2415.0
 127         7.6       22.0     2189.0
 128        14.4       19.5     1033.0
 129        14.2       23.8     1518.0
 130         7.8       17.2     1217.0
 131         8.7       22.0     2406.0
 132        11.1       23.8     2566.0
 133        15.5       26.0     2624.0
 134        15.0       25.3     2347.0
 135        15.4       26.3     2339.0
 136        11.4       27.3     2238.0
 137         9.1       19.3     2514.0
 138         5.4       13.5      905.0
 139         3.7       10.3      366.0
 140         2.2       12.9     1474.0
 141        -0.9       16.3     2082.0
 142         1.6       18.9     2882.0
 143         8.9       21.8     2624.0
 144         8.8       20.1     2154.0
 145         8.8       26.3     2362.0
 146        14.2       25.0     1763.0
 147        13.7       17.2      708.0
 148        11.6       14.5      300.0
 149        10.2       16.5     1360.0
 150         9.8       17.3     1533.0
 151         9.2       15.3     1083.0
 152         9.8       17.7     1810.0
 153        10.8       18.9     1398.0
 154        11.7       18.2     1964.0
 155         8.6       17.1     1674.0
 156         7.3       15.9     1360.0
 157         6.9       15.0     1111.0
 158         6.8       14.0      650.0
 159         8.8       18.7     1122.0
 160         8.8       16.9      897.0
```

Appendix V

Simulation Results of the Mono Cultures

```
AEF881R.OUT
FRF881R.OUT
AEF881N.OUT
FRF881N.OUT
AEF881W.OUT
FRF881W.OUT
```

File : AEF881R.OUT

Arrhenatherum elatius ; fertilized/till 1st cut ; 1988.
Mono culture.

TIME (d)	DAY (-)	RADABS (J/cm2.d)	RADPER (%)	HGT (cm)	LAI (-)
1.	88	59.	100.	5.0	.44
2.	89	78.	100.	5.4	.44
3.	90	58.	100.	5.7	.44
4.	91	170.	100.	6.1	.44
5.	92	154.	100.	6.4	.46
6.	93	196.	100.	6.8	.47
7.	94	140.	100.	7.1	.50
8.	95	88.	100.	7.5	.51
9.	96	209.	100.	7.9	.51
10.	97	177.	100.	8.2	.53
11.	98	101.	100.	8.6	.54
12.	99	164.	100.	8.9	.54
13.	100	192.	100.	9.3	.55
14.	101	216.	100.	9.6	.56
15.	102	233.	100.	10.0	.58
16.	103	277.	100.	10.7	.65
17.	104	329.	100.	11.4	.73
18.	105	317.	100.	12.1	.83
19.	106	159.	100.	12.9	.92
20.	107	192.	100.	13.6	.98
21.	108	372.	100.	14.3	1.05
22.	109	374.	100.	15.0	1.17
23.	110	222.	100.	15.7	1.29
24.	111	229.	100.	16.4	1.38
25.	112	549.	100.	17.1	1.46
26.	113	620.	100.	17.9	1.65
27.	114	734.	100.	18.6	1.87
28.	115	599.	100.	19.3	2.14
29.	116	585.	100.	20.0	2.36
30.	117	751.	100.	22.9	2.44
31.	118	529.	100.	25.7	2.54
32.	119	423.	100.	28.6	2.60
33.	120	641.	100.	31.4	2.65
34.	121	623.	100.	34.3	2.74
35.	122	765.	100.	37.1	2.82
36.	123	498.	100.	40.0	2.92
37.	124	440.	100.	42.9	2.98
38.	125	599.	100.	45.7	3.03
39.	126	939.	100.	48.6	3.11
40.	127	863.	100.	51.4	3.25
41.	128	412.	100.	54.3	3.37
42.	129	608.	100.	57.1	3.41
43.	130	491.	100.	60.0	3.49
44.	131	975.	100.	62.9	3.55
45.	132	1051.	100.	65.7	3.69
46.	133	1087.	100.	68.6	3.85
47.	134	982.	100.	71.4	4.01
48.	135	986.	100.	74.3	4.14
49.	136	950.	100.	77.1	4.27
50.	137	1073.	100.	80.0	4.39
51.	138	385.	100.	80.0	4.33
52.	139	155.	100.	80.0	4.23
53.	140	621.	100.	80.0	4.14
54.	141	874.	100.	80.0	4.06
55.	142	1205.	100.	80.0	3.99
56.	143	1094.	100.	80.0	3.94
57.	144	894.	100.	80.0	3.88
58.	145	977.	100.	80.0	3.82
59.	146	726.	100.	80.0	3.75
60.	147	290.	100.	80.0	3.68
61.	148	122.	100.	80.0	3.60
62.	149	549.	100.	80.0	3.51
63.	150	616.	100.	80.0	3.44
64.	151	432.	100.	80.0	3.37
65.	152	717.	100.	80.0	3.29
66.	153	551.	100.	80.0	3.23
67.	154	768.	100.	80.0	3.16
68.	155	651.	100.	80.0	3.11
69.	156	525.	100.	80.0	3.04
70.	157	425.	100.	80.0	2.98
71.	158	247.	100.	80.0	2.91

File : FRF881R.OUT

Festuca rubra ; fertilized/till 1st cut ; 1988.
Mono culture.

TIME (d)	DAY (-)	RADABS (J/cm2.d)	RADPER (%)	HGT (cm)	LAI (-)
1.	88	49.	100.	5.0	.43
2.	89	66.	100.	5.0	.44
3.	90	50.	100.	5.0	.44
4.	91	150.	100.	5.0	.45
5.	92	135.	100.	5.0	.47
6.	93	172.	100.	5.0	.49
7.	94	123.	100.	5.0	.51
8.	95	78.	100.	5.0	.53
9.	96	189.	100.	5.0	.54
10.	97	161.	100.	5.0	.57
11.	98	93.	100.	5.0	.59
12.	99	154.	100.	5.0	.60
13.	100	183.	100.	5.0	.63
14.	101	210.	100.	5.0	.65
15.	102	229.	100.	5.0	.69
16.	103	256.	100.	6.1	.71
17.	104	285.	100.	7.1	.74
18.	105	258.	100.	8.2	.77
19.	106	122.	100.	9.3	.79
20.	107	140.	100.	10.4	.78
21.	108	257.	100.	11.4	.78
22.	109	244.	100.	12.5	.79
23.	110	136.	100.	13.6	.81
24.	111	134.	100.	14.6	.80
25.	112	307.	100.	15.7	.79
26.	113	327.	100.	16.8	.81
27.	114	368.	100.	17.9	.83
28.	115	287.	100.	18.9	.85
29.	116	269.	100.	20.0	.86
30.	117	349.	100.	21.4	.88
31.	118	250.	100.	22.9	.92
32.	119	203.	100.	24.3	.95
33.	120	310.	100.	25.7	.97
34.	121	305.	100.	27.1	1.01
35.	122	380.	100.	28.6	1.04
36.	123	252.	100.	30.0	1.08
37.	124	225.	100.	31.4	1.11
38.	125	310.	100.	32.9	1.13
39.	126	492.	100.	34.3	1.17
40.	127	462.	100.	35.7	1.23
41.	128	225.	100.	37.1	1.28
42.	129	335.	100.	38.6	1.31
43.	130	274.	100.	40.0	1.35
44.	131	551.	100.	41.4	1.38
45.	132	608.	100.	42.9	1.45
46.	133	644.	100.	44.3	1.52
47.	134	596.	100.	45.7	1.61
48.	135	612.	100.	47.1	1.68
49.	136	603.	100.	48.6	1.76
50.	137	695.	100.	50.0	1.84
51.	138	256.	100.	50.0	1.91
52.	139	104.	100.	50.0	1.92
53.	140	415.	100.	50.0	1.90
54.	141	592.	100.	50.0	1.92
55.	142	833.	100.	50.0	1.98
56.	143	778.	100.	50.0	2.07
57.	144	652.	100.	50.0	2.15
58.	145	726.	100.	50.0	2.21
59.	146	551.	100.	50.0	2.28
60.	147	223.	100.	50.0	2.32
61.	148	94.	100.	50.0	2.31
62.	149	425.	100.	50.0	2.28
63.	150	482.	100.	50.0	2.30
64.	151	342.	100.	50.0	2.33
65.	152	573.	100.	50.0	2.33
66.	153	447.	100.	50.0	2.37
67.	154	630.	100.	50.0	2.39
68.	155	543.	100.	50.0	2.44
69.	156	444.	100.	50.0	2.47
70.	157	364.	100.	50.0	2.49
71.	158	213.	100.	50.0	2.50

File : AEF881N.OUT

Arrhenatherum elatius ; fertilized/till 1st cut ; 1988.
Mono culture.

TIME (d)	ANSL (g/m2)	RLI (m/m2)	RNU (g/m2.d)	RNUPER (%)	CNRT (g/g)	CNLV (g/g)	REDN (-)	ANLB (g/m2)	ANDB (g/m2)
1.	.050	9672.	.050	100.	.010	.025	.608	1.660	.000
2.	.050	9629.	.050	100.	.009	.033	.897	1.703	.007
3.	.050	9638.	.050	100.	.009	.033	.920	1.746	.014
4.	.050	9622.	.050	100.	.009	.034	.950	1.790	.020
5.	.050	9771.	.050	100.	.009	.033	.938	1.833	.027
6.	.050	9893.	.050	100.	.009	.033	.934	1.876	.034
7.	.050	10071.	.050	100.	.009	.032	.919	1.919	.041
8.	.050	10166.	.050	100.	.009	.032	.922	1.961	.049
9.	.050	10187.	.050	100.	.009	.033	.942	2.004	.056
10.	.050	10383.	.050	100.	.009	.032	.924	2.046	.064
11.	.050	10527.	.050	100.	.009	.032	.919	2.089	.071
12.	.050	10563.	.050	100.	.009	.032	.936	2.131	.079
13.	5.550	10690.	1.466	100.	.009	.032	.934	2.173	.087
14.	4.134	10854.	.129	100.	.014	.052	1.000	3.630	.096
15.	4.055	11073.	.186	100.	.014	.051	1.000	3.751	.104
16.	3.919	11059.	.228	100.	.014	.051	1.000	3.929	.112
17.	3.741	11062.	.276	100.	.014	.051	1.000	4.148	.121
18.	3.515	11088.	.258	100.	.014	.050	1.000	4.415	.130
19.	3.307	11108.	.092	100.	.014	.050	1.000	4.663	.140
20.	3.265	11062.	.123	100.	.014	.050	1.000	4.746	.149
21.	3.192	11031.	.300	100.	.014	.050	1.000	4.859	.159
22.	2.942	11074.	.296	100.	.014	.049	1.000	5.149	.169
23.	2.696	11118.	.138	100.	.013	.049	1.000	5.435	.179
24.	2.608	11098.	.142	100.	.013	.049	1.000	5.562	.190
25.	2.516	11082.	.451	100.	.013	.048	1.000	5.694	.200
26.	2.114	11198.	.510	100.	.013	.048	1.000	6.135	.211
27.	1.654	11342.	.608	100.	.013	.048	1.000	6.633	.223
28.	1.096	11532.	.465	100.	.013	.048	1.000	7.229	.235
29.	.681	11664.	.367	100.	.013	.047	1.000	7.682	.248
30.	.364	11628.	.364	100.	.013	.047	1.000	8.035	.261
31.	.050	11615.	.050	100.	.013	.046	1.000	8.385	.275
32.	.050	11572.	.050	100.	.012	.044	1.000	8.422	.288
33.	.050	11514.	.050	100.	.012	.043	1.000	8.458	.302
34.	.050	11487.	.050	100.	.012	.042	1.000	8.494	.316
35.	.050	11458.	.050	100.	.011	.040	1.000	8.529	.331
36.	.050	11449.	.050	100.	.011	.038	1.000	8.565	.345
37.	.050	11403.	.050	100.	.010	.037	1.000	8.601	.359
38.	.050	11349.	.050	100.	.010	.036	1.000	8.636	.374
39.	.050	11318.	.050	100.	.010	.035	1.000	8.671	.389
40.	.050	11334.	.050	100.	.009	.033	1.000	8.706	.404
41.	.050	11340.	.050	100.	.009	.032	1.000	8.741	.419
42.	.050	11283.	.050	100.	.009	.032	1.000	8.776	.434
43.	.050	11254.	.050	100.	.009	.031	1.000	8.810	.450
44.	.050	11209.	.050	100.	.008	.030	1.000	8.845	.465
45.	.050	11231.	.050	100.	.008	.029	1.000	8.879	.481
46.	.050	11264.	.050	100.	.008	.027	1.000	8.913	.497
47.	.050	11301.	.050	100.	.007	.026	.950	8.947	.513
48.	.050	11316.	.050	100.	.007	.025	.910	8.980	.530
49.	.050	11326.	.050	100.	.007	.024	.876	9.013	.547
50.	.050	11328.	.050	100.	.007	.024	.847	9.046	.564
51.	.050	11340.	.050	100.	.006	.023	.820	9.078	.582
52.	.050	11270.	.050	100.	.006	.023	.825	9.111	.599
53.	.050	11175.	.050	100.	.007	.023	.839	9.143	.617
54.	.050	11135.	.050	100.	.006	.023	.833	9.176	.634
55.	.050	11123.	.050	100.	.006	.022	.816	9.209	.651
56.	.050	11148.	.050	100.	.006	.022	.788	9.242	.668
57.	.050	11155.	.050	100.	.006	.021	.767	9.275	.685
58.	.050	11138.	.050	100.	.006	.021	.755	9.309	.701
59.	.050	11128.	.050	100.	.006	.021	.741	9.342	.718
60.	.050	11090.	.050	100.	.006	.020	.736	9.375	.735
61.	.050	11009.	.050	100.	.006	.020	.746	9.408	.752
62.	.050	10911.	.050	100.	.006	.020	.761	9.442	.768
63.	.050	10860.	.050	100.	.006	.020	.762	9.476	.784
64.	.050	10816.	.050	100.	.006	.020	.760	9.510	.800
65.	.050	10753.	.050	100.	.006	.020	.765	9.544	.816
66.	.050	10721.	.050	100.	.006	.020	.761	9.578	.832
67.	.050	10671.	.050	100.	.006	.020	.762	9.612	.848
68.	.050	10645.	.050	100.	.006	.020	.756	9.646	.864
69.	.050	10606.	.050	100.	.006	.019	.754	9.681	.879
70.	.050	10555.	.050	100.	.006	.019	.757	9.715	.895
71.	.050	10494.	.050	100.	.005	.019	.763	9.750	.910

File : FRF881N.OUT

Festuca rubra ; fertilized/till 1st cut ; 1988.
Mono culture.

TIME (d)	ANSL (g/m2)	RLI (m/m2)	RNU (g/m2.d)	RNUPER (%)	CNRT (g/g)	CNLV (g/g)	REDN (-)	ANLB (g/m2)	ANDB (g/m2)
1.	.050	46118.	.050	100.	.010	.025	.615	3.290	.000
2.	.050	45754.	.050	100.	.009	.033	.893	3.326	.014
3.	.050	45488.	.050	100.	.009	.033	.914	3.363	.027
4.	.050	45181.	.050	100.	.009	.034	.938	3.400	.040
5.	.050	45186.	.050	100.	.009	.033	.943	3.436	.054
6.	.050	45148.	.050	100.	.009	.033	.950	3.473	.067
7.	.050	45228.	.050	100.	.009	.033	.951	3.509	.081
8.	.050	45156.	.050	100.	.009	.033	.961	3.546	.094
9.	.050	44948.	.050	100.	.009	.034	.980	3.582	.108
10.	.050	45102.	.050	100.	.009	.033	.977	3.619	.121
11.	.050	45162.	.050	100.	.009	.033	.980	3.655	.135
12.	.050	45007.	.050	100.	.009	.034	.996	3.691	.149
13.	5.550	45057.	2.116	100.	.009	.034	1.000	3.727	.163
14.	3.484	45202.	.098	100.	.014	.052	1.000	5.830	.176
15.	3.436	45433.	.145	100.	.014	.051	1.000	5.914	.190
16.	3.341	45574.	.168	100.	.014	.051	1.000	6.045	.205
17.	3.222	45785.	.193	100.	.014	.051	1.000	6.199	.219
18.	3.080	46069.	.161	100.	.014	.050	1.000	6.377	.234
19.	2.969	46279.	.023	100.	.014	.050	1.000	6.523	.249
20.	2.995	46133.	.040	100.	.014	.050	1.000	6.531	.264
21.	3.006	46034.	.152	100.	.014	.050	1.000	6.555	.279
22.	2.904	46242.	.135	100.	.014	.049	1.000	6.692	.295
23.	2.819	46413.	.029	100.	.013	.049	1.000	6.811	.310
24.	2.840	46304.	.026	100.	.013	.049	1.000	6.824	.326
25.	2.864	46190.	.188	100.	.013	.048	1.000	6.834	.342
26.	2.727	46526.	.202	100.	.013	.048	1.000	7.005	.358
27.	2.574	46913.	.235	100.	.013	.048	1.000	7.191	.374
28.	2.390	47401.	.153	100.	.013	.048	1.000	7.409	.391
29.	2.286	47673.	.157	100.	.013	.047	1.000	7.546	.408
30.	2.179	47336.	.235	100.	.013	.047	1.000	7.685	.425
31.	1.994	47045.	.131	100.	.013	.047	1.000	7.903	.443
32.	1.913	46705.	.081	100.	.013	.046	1.000	8.017	.460
33.	1.882	46343.	.186	100.	.013	.046	1.000	8.080	.478
34.	1.745	46041.	.178	100.	.013	.046	1.000	8.249	.496
35.	1.617	45739.	.248	100.	.013	.046	1.000	8.410	.513
36.	1.419	45479.	.119	100.	.013	.045	1.000	8.640	.531
37.	1.350	45155.	.091	100.	.013	.045	1.000	8.741	.549
38.	1.309	44821.	.170	100.	.012	.045	1.000	8.814	.567
39.	1.189	44534.	.342	100.	.012	.044	1.000	8.966	.585
40.	.897	44345.	.307	100.	.012	.044	1.000	9.290	.603
41.	.640	44142.	.077	100.	.012	.044	1.000	9.579	.621
42.	.613	43817.	.179	100.	.012	.044	1.000	9.637	.639
43.	.485	43554.	.118	100.	.012	.043	1.000	9.798	.658
44.	.416	43261.	.374	100.	.012	.043	1.000	9.898	.676
45.	.092	43115.	.092	100.	.012	.043	1.000	10.253	.695
46.	.050	43001.	.050	100.	.011	.041	1.000	10.327	.713
47.	.050	42906.	.050	100.	.011	.039	1.000	10.358	.732
48.	.050	42787.	.050	100.	.011	.038	1.000	10.388	.752
49.	.050	42677.	.050	100.	.010	.037	1.000	10.418	.772
50.	.050	42564.	.050	100.	.010	.035	1.000	10.448	.792
51.	.050	42500.	.050	100.	.010	.034	1.000	10.478	.812
52.	.050	42208.	.050	100.	.010	.034	1.000	10.507	.833
53.	.050	41840.	.050	100.	.010	.034	1.000	10.536	.854
54.	.050	41638.	.050	100.	.009	.033	1.000	10.565	.875
55.	.050	41530.	.050	100.	.009	.033	1.000	10.594	.896
56.	.050	41548.	.050	100.	.009	.031	1.000	10.623	.917
57.	.050	41537.	.050	100.	.008	.030	1.000	10.651	.939
58.	.050	41461.	.050	100.	.008	.029	1.000	10.679	.961
59.	.050	41424.	.050	100.	.008	.028	1.000	10.707	.983
60.	.050	41297.	.050	100.	.008	.028	1.000	10.733	1.007
61.	.050	41000.	.050	100.	.008	.028	1.000	10.760	1.030
62.	.050	40639.	.050	100.	.008	.028	1.000	10.787	1.053
63.	.050	40454.	.050	100.	.008	.028	1.000	10.814	1.076
64.	.050	40300.	.050	100.	.008	.027	1.000	10.840	1.100
65.	.050	40075.	.050	100.	.008	.027	1.000	10.867	1.123
66.	.050	39973.	.050	100.	.008	.026	1.000	10.893	1.147
67.	.050	39806.	.050	100.	.007	.026	1.000	10.920	1.170
68.	.050	39736.	.050	100.	.007	.026	1.000	10.946	1.194
69.	.050	39621.	.050	100.	.007	.025	1.000	10.972	1.218
70.	.050	39455.	.050	100.	.007	.025	1.000	10.997	1.243
71.	.050	39250.	.050	100.	.007	.025	1.000	11.022	1.268

File : AEF881W.OUT

Arrhenatherum elatius ; fertilized/till 1st cut ; 1988.
Mono culture.
All weights are expressed in g DM/m2.

TIME	WRT	WLV	WST	WER	WDRT	WDLV	WSH	WLB	WTOT
1.	105.4	20.1	7.1	.0	105.4	35.9	27.2	132.6	273.9
2.	104.9	20.2	7.2	.0	106.5	36.2	27.4	132.3	275.0
3.	105.0	20.6	7.4	.0	107.5	36.5	28.0	133.1	277.1
4.	104.9	20.9	7.6	.0	108.6	36.8	28.4	133.3	278.7
5.	106.5	22.2	8.1	.0	109.6	37.1	30.3	136.8	283.5
6.	107.8	23.4	8.5	.0	110.7	37.5	31.9	139.7	287.9
7.	109.8	25.0	9.0	.0	111.7	37.8	34.0	143.8	293.4
8.	110.8	26.0	9.4	.0	112.8	38.2	35.4	146.2	297.2
9.	111.0	26.4	9.7	.0	114.0	38.6	36.1	147.1	299.7
10.	113.2	28.1	10.3	.0	115.1	39.0	38.4	151.5	305.6
11.	114.7	29.4	10.8	.0	116.2	39.4	40.2	154.9	310.5
12.	115.1	29.9	11.0	.0	117.3	39.8	41.0	156.1	313.3
13.	116.5	31.1	11.5	.0	118.5	40.3	42.6	159.1	317.9
14.	118.3	32.5	12.0	.0	119.7	40.8	44.6	162.8	323.3
15.	120.7	34.3	12.7	.0	120.8	41.2	47.0	167.7	329.7
16.	120.5	37.0	15.4	.0	122.0	41.8	52.4	172.9	336.7
17.	120.6	40.3	18.6	.0	123.3	42.3	58.9	179.5	345.0
18.	120.8	44.2	22.5	.0	124.5	42.9	66.7	187.5	354.9
19.	121.1	47.9	26.2	.0	125.7	43.6	74.1	195.2	364.4
20.	120.6	49.4	28.1	.0	126.9	44.3	77.5	198.0	369.2
21.	120.2	51.3	30.3	.0	128.1	45.0	81.6	201.8	374.9
22.	120.7	55.7	34.7	.0	129.3	45.8	90.3	211.0	386.1
23.	121.2	60.0	39.0	.0	130.5	46.6	99.0	220.2	397.3
24.	121.0	62.2	41.6	.0	131.7	47.5	103.8	224.8	404.0
25.	120.8	64.4	44.3	.0	132.9	48.5	108.7	229.5	410.9
26.	122.0	71.0	50.8	.0	134.1	49.4	121.8	243.8	427.4
27.	123.6	78.5	58.0	.0	135.3	50.5	136.5	260.1	446.0
28.	125.7	87.4	66.6	.0	136.6	51.7	154.0	279.7	468.0
29.	127.1	94.4	73.6	.0	137.8	53.0	168.0	295.1	485.9
30.	126.7	96.7	85.5	1.1	139.1	54.4	183.3	310.0	503.5
31.	126.6	100.0	100.9	2.4	140.4	55.9	203.2	329.8	526.0
32.	126.1	101.8	111.6	3.4	141.6	57.4	216.8	342.9	541.9
33.	125.5	102.9	120.3	4.1	142.9	58.9	227.3	352.8	554.6
34.	125.2	105.4	133.4	5.3	144.2	60.4	244.1	369.2	573.8
35.	124.9	107.8	146.1	6.4	145.4	62.0	260.2	385.1	592.5
36.	124.8	111.0	161.7	7.8	146.7	63.6	280.4	405.2	615.5
37.	124.3	112.4	171.8	8.7	147.9	65.3	292.9	417.2	630.4
38.	123.7	113.5	180.8	9.5	149.1	67.0	303.8	427.5	643.6
39.	123.3	115.6	193.0	10.5	150.4	68.7	319.2	442.5	661.6
40.	123.5	119.8	212.2	12.2	151.6	70.4	344.2	467.7	689.8
41.	123.6	123.4	229.8	13.8	152.8	72.2	367.0	490.6	715.7
42.	123.0	124.2	238.2	14.5	154.1	74.1	376.9	499.9	728.0
43.	122.6	126.1	250.6	15.6	155.3	75.9	392.4	515.0	746.3
44.	122.2	127.3	260.6	16.5	156.5	77.8	404.5	526.6	761.0
45.	122.4	131.6	280.5	18.3	157.8	79.7	430.4	552.7	790.2
46.	122.8	136.2	302.0	20.2	159.0	81.7	458.3	581.1	821.8
47.	123.2	141.0	324.1	22.1	160.2	83.7	487.3	610.4	854.4
48.	123.3	144.8	343.2	23.8	161.4	85.9	511.8	635.1	882.4
49.	123.4	148.3	361.5	25.4	162.7	88.0	535.2	658.6	909.3
50.	123.4	151.3	378.5	26.9	163.9	90.3	556.7	680.1	934.3
51.	123.6	150.7	398.9	30.7	165.1	92.5	580.3	703.9	961.6
52.	122.8	149.0	406.0	32.0	166.4	94.8	587.1	709.9	971.0
53.	121.8	147.0	408.9	32.6	167.6	97.0	588.5	710.3	974.9
54.	121.3	145.7	420.7	34.8	168.8	99.2	601.1	722.5	990.5
55.	121.2	144.8	437.0	37.8	170.0	101.4	619.7	740.9	1012.4
56.	121.5	144.4	459.2	42.0	171.3	103.6	645.5	767.0	1041.9
57.	121.6	143.8	478.5	45.6	172.5	105.7	667.9	789.5	1067.7
58.	121.4	142.9	494.0	48.5	173.7	107.9	685.3	806.7	1088.3
59.	121.3	142.1	510.6	51.6	174.9	110.0	704.2	825.5	1110.4
60.	120.9	140.9	522.7	53.8	176.1	112.2	717.4	838.2	1126.5
61.	120.0	139.2	527.5	54.7	177.3	114.3	721.3	841.3	1132.9
62.	118.9	137.3	529.5	55.1	178.5	116.4	721.9	840.8	1135.7
63.	118.3	135.9	538.9	56.9	179.7	118.4	731.7	850.1	1148.2
64.	117.9	134.7	549.5	58.8	180.9	120.5	743.0	860.9	1162.3
65.	117.2	133.3	556.9	60.2	182.1	122.5	750.4	867.6	1172.1
66.	116.8	132.3	569.2	62.5	183.2	124.5	764.0	880.9	1188.6
67.	116.3	131.1	578.6	64.3	184.4	126.5	774.0	890.3	1201.2
68.	116.0	130.2	591.8	66.7	185.6	128.5	788.7	904.7	1218.7
69.	115.6	129.1	602.9	68.8	186.7	130.4	800.8	916.3	1233.5
70.	115.0	127.9	611.8	70.5	187.9	132.3	810.1	925.1	1245.4
71.	114.4	126.5	619.0	71.8	189.0	134.3	817.4	931.7	1255.0

File : FRF881W.OUT

Festuca rubra ; fertilized/till 1st cut ; 1988.
Mono culture.
All weights are expressed in g DM/m2.

TIME	WRT	WLV	WST	WER	WDRT	WDLV	WSH	WLB	WTOT
1.	212.7	39.1	12.2	.0	212.7	92.6	51.3	264.0	569.3
2.	211.0	38.8	12.3	.0	214.8	93.2	51.2	262.2	570.2
3.	209.8	38.9	12.6	.0	216.9	93.8	51.5	261.3	572.0
4.	208.4	38.8	12.8	.0	219.0	94.4	51.6	259.9	573.3
5.	208.4	39.7	13.4	.0	221.1	94.9	53.1	261.5	577.5
6.	208.2	40.5	13.9	.0	223.2	95.5	54.4	262.6	581.4
7.	208.6	41.7	14.6	.0	225.3	96.1	56.2	264.8	586.3
8.	208.3	42.3	15.1	.0	227.4	96.8	57.4	265.6	589.8
9.	207.3	42.5	15.4	.0	229.5	97.4	57.9	265.2	592.0
10.	208.0	43.8	16.2	.0	231.5	98.0	60.0	268.0	597.6
11.	208.3	44.9	16.8	.0	233.6	98.7	61.7	270.0	602.3
12.	207.6	45.2	17.2	.0	235.7	99.4	62.4	270.0	605.0
13.	207.8	46.2	17.8	.0	237.8	100.0	64.0	271.8	609.6
14.	208.5	47.5	18.6	.0	239.8	100.7	66.1	274.6	615.1
15.	209.5	49.0	19.5	.0	241.9	101.4	68.5	278.1	621.4
16.	210.2	51.7	20.2	.0	244.0	102.2	71.9	282.1	628.3
17.	211.2	54.8	21.0	.0	246.1	103.0	75.7	286.9	636.0
18.	212.5	58.2	21.8	.0	248.2	103.8	80.1	292.5	644.6
19.	213.4	61.2	22.6	.0	250.4	104.7	83.8	297.3	652.3
20.	212.8	62.1	22.9	.0	252.5	105.6	85.1	297.9	655.9
21.	212.3	63.3	23.4	.0	254.6	106.5	86.7	299.0	660.1
22.	213.3	66.2	24.1	.0	256.7	107.5	90.3	303.6	667.8
23.	214.1	68.9	24.9	.0	258.9	108.4	93.7	307.8	675.1
24.	213.6	69.9	25.3	.0	261.0	109.5	95.2	308.7	679.2
25.	213.0	70.8	25.7	.0	263.2	110.5	96.5	309.6	683.2
26.	214.6	74.4	26.6	.0	265.3	111.6	101.0	315.6	692.4
27.	216.4	78.2	27.6	.0	267.4	112.7	105.8	322.1	702.3
28.	218.6	82.5	28.7	.0	269.6	113.9	111.2	329.8	713.3
29.	219.9	85.6	29.5	.0	271.8	115.1	115.1	335.0	721.9
30.	218.3	87.2	32.7	1.4	274.0	116.4	121.3	339.6	730.0
31.	217.0	89.7	36.8	3.2	276.2	117.7	129.6	346.6	740.5
32.	215.4	91.0	39.7	4.4	278.3	119.1	135.2	350.6	748.0
33.	213.7	91.8	42.1	5.5	280.5	120.4	139.4	353.1	754.0
34.	212.3	93.8	45.7	7.0	282.6	121.8	146.6	358.9	763.3
35.	211.0	95.7	49.3	8.6	284.7	123.2	153.6	364.5	772.5
36.	209.8	98.4	53.7	10.5	286.9	124.6	162.6	372.4	783.9
37.	208.3	99.6	56.7	11.8	289.0	126.1	168.1	376.4	791.4
38.	206.7	100.6	59.3	13.0	291.0	127.6	172.8	379.5	798.2
39.	205.4	102.4	62.9	14.5	293.1	129.1	179.8	385.2	807.5
40.	204.5	106.2	68.7	17.1	295.2	130.7	191.9	396.4	822.2
41.	203.6	109.6	74.1	19.4	297.2	132.2	203.1	406.6	836.1
42.	202.1	110.4	76.7	20.6	299.2	133.9	207.6	409.7	842.8
43.	200.9	112.3	80.6	22.3	301.3	135.5	215.2	416.1	852.9
44.	199.5	113.6	83.8	23.7	303.3	137.2	221.1	420.6	861.1
45.	198.9	117.8	90.3	26.5	305.3	138.9	234.6	433.5	877.7
46.	198.3	122.6	97.4	29.6	307.3	140.7	249.6	448.0	895.9
47.	197.9	127.8	104.9	32.9	309.2	142.5	265.6	463.5	915.2
48.	197.3	132.3	111.9	35.9	311.2	144.5	280.1	477.4	933.1
49.	196.8	136.9	119.1	39.0	313.2	146.4	295.0	491.8	951.5
50.	196.3	141.4	126.1	42.1	315.2	148.5	309.6	505.9	969.6
51.	196.0	147.6	135.3	43.8	317.1	150.6	326.6	522.7	990.4
52.	194.7	148.4	138.7	44.4	319.1	152.8	331.5	526.2	998.1
53.	193.0	147.5	140.1	44.6	321.0	155.1	332.1	525.1	1001.2
54.	192.0	150.2	145.5	45.6	323.0	157.3	341.4	533.4	1013.7
55.	191.5	155.1	153.3	47.0	324.9	159.5	355.5	547.0	1031.4
56.	191.6	162.7	164.3	49.0	326.8	161.8	376.1	567.8	1056.4
57.	191.6	169.6	174.6	50.9	328.7	164.3	395.2	586.7	1079.7
58.	191.2	174.9	183.2	52.5	330.6	166.8	410.6	601.9	1099.3
59.	191.1	181.0	192.8	54.2	332.5	169.5	428.1	619.1	1121.1
60.	190.5	184.9	200.1	55.5	334.4	172.2	440.5	631.0	1137.6
61.	189.1	184.8	203.0	56.1	336.4	174.9	443.9	633.0	1144.3
62.	187.4	183.2	204.3	56.3	338.2	177.7	443.8	631.2	1147.2
63.	186.6	185.5	209.9	57.3	340.1	180.5	452.8	639.3	1159.9
64.	185.9	188.5	216.2	58.5	342.0	183.3	463.3	649.1	1174.4
65.	184.8	189.8	220.8	59.3	343.8	186.1	469.9	654.7	1184.6
66.	184.4	193.8	228.3	60.7	345.7	188.9	482.9	667.2	1201.8
67.	183.6	196.3	234.2	61.8	347.5	191.8	492.3	675.9	1215.2
68.	183.3	200.9	242.6	63.3	349.4	194.8	506.7	690.0	1234.2
69.	182.7	204.4	249.7	64.6	351.2	197.8	518.7	701.4	1250.4
70.	182.0	206.7	255.6	65.6	353.0	200.9	527.9	709.9	1263.7
71.	181.0	207.9	260.4	66.5	354.9	204.0	534.8	715.9	1274.7

Appendix VI

Simulation Results of the Mixed Culture

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AEF881R.OUT
FRF881R.OUT
AEF881N.OUT
FRF881N.OUT
AEF881W.OUT
FRF881W.OUT
  CHECK.OUT
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File : AEF881R.OUT

Arrhenatherum elatius ; fertilized/till 1st cut ; 1988.
Mixed culture.

TIME (d)	DAY (-)	RADABS (J/cm2.d)	RADPER (%)	HGT (cm)	LAI (-)
1.	88	30.	55.	5.0	.22
2.	89	39.	55.	5.4	.22
3.	90	29.	54.	5.7	.22
4.	91	86.	54.	6.1	.22
5.	92	78.	54.	6.4	.23
6.	93	99.	54.	6.8	.23
7.	94	71.	54.	7.1	.24
8.	95	44.	54.	7.5	.25
9.	96	105.	53.	7.9	.25
10.	97	89.	53.	8.2	.26
11.	98	50.	53.	8.6	.26
12.	99	82.	52.	8.9	.26
13.	100	95.	52.	9.3	.26
14.	101	107.	51.	9.6	.26
15.	102	115.	51.	10.0	.27
16.	103	139.	53.	10.7	.31
17.	104	166.	55.	11.4	.35
18.	105	163.	58.	12.1	.40
19.	106	83.	60.	12.9	.45
20.	107	101.	62.	13.6	.47
21.	108	198.	63.	14.3	.51
22.	109	203.	66.	15.0	.57
23.	110	123.	68.	15.7	.64
24.	111	129.	70.	16.4	.68
25.	112	314.	72.	17.1	.73
26.	113	367.	74.	17.9	.84
27.	114	450.	77.	18.6	.97
28.	115	384.	79.	19.3	1.13
29.	116	388.	82.	20.0	1.27
30.	117	507.	82.	22.9	1.32
31.	118	364.	83.	25.7	1.39
32.	119	296.	84.	28.6	1.44
33.	120	453.	84.	31.4	1.48
34.	121	448.	85.	34.3	1.54
35.	122	558.	86.	37.1	1.60
36.	123	369.	86.	40.0	1.68
37.	124	330.	87.	42.9	1.73
38.	125	454.	87.	45.7	1.77
39.	126	720.	88.	48.6	1.84
40.	127	674.	89.	51.4	1.94
41.	128	327.	89.	54.3	2.04
42.	129	486.	90.	57.1	2.08
43.	130	396.	90.	60.0	2.15
44.	131	793.	90.	62.9	2.20
45.	132	869.	91.	65.7	2.33
46.	133	912.	92.	68.6	2.46
47.	134	837.	92.	71.4	2.60
48.	135	850.	93.	74.3	2.72
49.	136	827.	93.	77.1	2.83
50.	137	942.	94.	80.0	2.93
51.	138	338.	94.	80.0	2.90
52.	139	136.	94.	80.0	2.84
53.	140	542.	94.	80.0	2.78
54.	141	762.	93.	80.0	2.73
55.	142	1049.	93.	80.0	2.69
56.	143	952.	93.	80.0	2.66
57.	144	778.	93.	80.0	2.63
58.	145	848.	93.	80.0	2.59
59.	146	629.	93.	80.0	2.55
60.	147	251.	93.	80.0	2.50
61.	148	105.	93.	80.0	2.45
62.	149	473.	93.	80.0	2.39
63.	150	528.	93.	80.0	2.34
64.	151	370.	92.	80.0	2.29
65.	152	612.	92.	80.0	2.25
66.	153	469.	92.	80.0	2.20
67.	154	653.	92.	80.0	2.16
68.	155	552.	92.	80.0	2.12
69.	156	444.	92.	80.0	2.08
70.	157	359.	91.	80.0	2.04
71.	158	208.	91.	80.0	1.99

File : FRF881R.OUT

Festuca rubra ; fertilized/till 1st cut ; 1988.
Mixed culture.

TIME (d)	DAY (-)	RADABS (J/cm2.d)	RADPER (%)	HGT (cm)	LAI (-)
1.	88	24.	45.	5.0	.22
2.	89	33.	45.	5.0	.22
3.	90	25.	46.	5.0	.22
4.	91	74.	46.	5.0	.23
5.	92	66.	46.	5.0	.24
6.	93	84.	46.	5.0	.24
7.	94	60.	46.	5.0	.26
8.	95	38.	46.	5.0	.27
9.	96	92.	47.	5.0	.27
10.	97	78.	47.	5.0	.28
11.	98	45.	47.	5.0	.30
12.	99	75.	48.	5.0	.30
13.	100	88.	48.	5.0	.31
14.	101	101.	49.	5.0	.33
15.	102	110.	49.	5.0	.34
16.	103	122.	47.	6.1	.35
17.	104	134.	45.	7.1	.37
18.	105	119.	42.	8.2	.38
19.	106	55.	40.	9.3	.39
20.	107	63.	38.	10.4	.38
21.	108	114.	37.	11.4	.38
22.	109	105.	34.	12.5	.39
23.	110	58.	32.	13.6	.39
24.	111	56.	30.	14.6	.39
25.	112	125.	28.	15.7	.38
26.	113	127.	26.	16.8	.38
27.	114	136.	23.	17.9	.39
28.	115	99.	21.	18.9	.39
29.	116	88.	18.	20.0	.39
30.	117	109.	18.	21.4	.40
31.	118	74.	17.	22.9	.41
32.	119	57.	16.	24.3	.42
33.	120	84.	16.	25.7	.43
34.	121	79.	15.	27.1	.44
35.	122	93.	14.	28.6	.44
36.	123	58.	14.	30.0	.45
37.	124	50.	13.	31.4	.46
38.	125	66.	13.	32.9	.46
39.	126	100.	12.	34.3	.47
40.	127	87.	11.	35.7	.48
41.	128	39.	11.	37.1	.49
42.	129	57.	10.	38.6	.50
43.	130	44.	10.	40.0	.50
44.	131	85.	10.	41.4	.51
45.	132	86.	9.	42.9	.52
46.	133	83.	8.	44.3	.53
47.	134	70.	8.	45.7	.53
48.	135	66.	7.	47.1	.54
49.	136	60.	7.	48.6	.55
50.	137	64.	6.	50.0	.56
51.	138	23.	6.	50.0	.55
52.	139	9.	6.	50.0	.55
53.	140	38.	6.	50.0	.54
54.	141	53.	7.	50.0	.53
55.	142	74.	7.	50.0	.53
56.	143	68.	7.	50.0	.53
57.	144	56.	7.	50.0	.53
58.	145	62.	7.	50.0	.53
59.	146	47.	7.	50.0	.53
60.	147	19.	7.	50.0	.53
61.	148	8.	7.	50.0	.52
62.	149	37.	7.	50.0	.51
63.	150	43.	7.	50.0	.51
64.	151	31.	8.	50.0	.51
65.	152	52.	8.	50.0	.50
66.	153	41.	8.	50.0	.50
67.	154	58.	8.	50.0	.50
68.	155	50.	8.	50.0	.50
69.	156	41.	8.	50.0	.49
70.	157	34.	9.	50.0	.49
71.	158	20.	9.	50.0	.49

File : AEF881N.OUT

Arrhenatherum elatius ; fertilized/till 1st cut ; 1988.
Mixed culture.

TIME (d)	ANSL (g/m2)	RLI (m/m2)	RNU (g/m2.d)	RNUPER (%)	CNRT (g/g)	CNLV (g/g)	REDN (-)	ANLB (g/m2)	ANDB (g/m2)
1.	.050	4836.	.009	17.	.010	.025	.608	.830	.000
2.	.050	4815.	.009	17.	.009	.032	.874	.835	.003
3.	.050	4819.	.009	17.	.009	.032	.875	.841	.007
4.	.050	4809.	.009	18.	.009	.032	.882	.846	.010
5.	.050	4877.	.009	18.	.008	.031	.854	.851	.014
6.	.050	4929.	.009	18.	.008	.030	.835	.857	.017
7.	.050	5005.	.009	18.	.008	.029	.807	.862	.021
8.	.050	5042.	.009	18.	.008	.029	.797	.868	.024
9.	.050	5045.	.009	18.	.008	.029	.801	.873	.028
10.	.050	5122.	.009	18.	.008	.028	.776	.878	.032
11.	.050	5175.	.009	19.	.008	.028	.761	.884	.035
12.	.050	5181.	.009	19.	.008	.028	.764	.889	.039
13.	5.550	5224.	.843	49.	.007	.027	.755	.895	.043
14.	3.890	5280.	.064	58.	.014	.052	1.000	1.734	.047
15.	3.830	5388.	.093	58.	.014	.051	1.000	1.794	.051
16.	3.720	5382.	.115	60.	.014	.051	1.000	1.883	.055
17.	3.576	5385.	.141	62.	.014	.051	1.000	1.994	.060
18.	3.398	5400.	.134	65.	.014	.050	1.000	2.131	.064
19.	3.243	5413.	.050	88.	.014	.050	1.000	2.260	.069
20.	3.235	5393.	.067	83.	.014	.050	1.000	2.306	.073
21.	3.204	5381.	.163	72.	.014	.050	1.000	2.369	.078
22.	3.029	5409.	.165	76.	.014	.049	1.000	2.527	.083
23.	2.862	5438.	.082	94.	.013	.049	1.000	2.686	.088
24.	2.825	5435.	.086	96.	.013	.049	1.000	2.763	.093
25.	2.786	5434.	.264	80.	.013	.048	1.000	2.843	.098
26.	2.503	5509.	.310	82.	.013	.048	1.000	3.102	.104
27.	2.175	5606.	.383	84.	.013	.048	1.000	3.406	.109
28.	1.766	5736.	.311	89.	.013	.048	1.000	3.783	.115
29.	1.466	5837.	.258	88.	.013	.047	1.000	4.088	.122
30.	1.223	5832.	.351	86.	.013	.047	1.000	4.339	.129
31.	.866	5843.	.229	92.	.013	.047	1.000	4.683	.136
32.	.668	5835.	.170	99.	.013	.046	1.000	4.905	.143
33.	.546	5817.	.293	91.	.013	.046	1.000	5.067	.151
34.	.274	5822.	.251	92.	.013	.046	1.000	5.353	.158
35.	.050	5825.	.013	27.	.013	.045	1.000	5.596	.166
36.	.050	5843.	.048	96.	.012	.042	1.000	5.601	.174
37.	.050	5836.	.050	100.	.011	.041	1.000	5.642	.182
38.	.050	5823.	.041	81.	.011	.040	1.000	5.683	.190
39.	.050	5827.	.011	21.	.011	.038	1.000	5.716	.198
40.	.050	5868.	.019	39.	.010	.036	1.000	5.718	.206
41.	.050	5902.	.050	100.	.009	.034	1.000	5.729	.215
42.	.050	5888.	.050	100.	.009	.033	1.000	5.770	.224
43.	.050	5896.	.050	100.	.009	.032	1.000	5.811	.232
44.	.050	5892.	.025	49.	.009	.031	1.000	5.852	.242
45.	.050	5942.	.024	48.	.008	.029	1.000	5.868	.251
46.	.050	6002.	.027	55.	.008	.027	1.000	5.882	.260
47.	.050	6067.	.040	80.	.007	.026	.925	5.900	.270
48.	.050	6113.	.044	87.	.007	.025	.873	5.930	.280
49.	.050	6154.	.049	99.	.007	.024	.829	5.963	.291
50.	.050	6187.	.048	96.	.006	.023	.796	6.001	.301
51.	.050	6228.	.050	100.	.006	.022	.763	6.039	.312
52.	.050	6202.	.050	100.	.006	.022	.767	6.078	.323
53.	.050	6154.	.050	100.	.006	.022	.783	6.117	.334
54.	.050	6151.	.050	100.	.006	.022	.775	6.156	.345
55.	.050	6171.	.039	78.	.006	.021	.757	6.195	.356
56.	.050	6218.	.045	90.	.006	.021	.724	6.224	.366
57.	.050	6251.	.050	100.	.006	.020	.700	6.258	.377
58.	.050	6263.	.050	100.	.006	.020	.688	6.297	.388
59.	.050	6281.	.050	100.	.005	.019	.674	6.337	.398
60.	.050	6277.	.050	100.	.005	.019	.670	6.376	.409
61.	.050	6237.	.050	100.	.005	.019	.680	6.415	.420
62.	.050	6184.	.050	100.	.006	.019	.696	6.455	.430
63.	.050	6168.	.050	100.	.005	.019	.698	6.494	.440
64.	.050	6157.	.050	100.	.005	.019	.697	6.534	.451
65.	.050	6131.	.050	100.	.005	.019	.703	6.574	.461
66.	.050	6129.	.050	100.	.005	.019	.698	6.614	.471
67.	.050	6113.	.050	100.	.005	.019	.700	6.654	.481
68.	.050	6114.	.050	100.	.005	.019	.695	6.694	.491
69.	.050	6106.	.050	100.	.005	.018	.694	6.734	.501
70.	.050	6087.	.050	100.	.005	.018	.698	6.774	.511
71.	.050	6061.	.050	100.	.005	.018	.705	6.814	.521

File : FRF881N.OUT

Festuca rubra ; fertilized/till 1st cut ; 1988.
Mixed culture.

TIME (d)	ANSL (g/m2)	RLI (m/m2)	RNU (g/m2.d)	RNUPER (%)	CNRT (g/g)	CNLV (g/g)	REDN (-)	ANLB (g/m2)	ANDB (g/m2)
1.	.050	23059.	.041	83.	.010	.025	.615	1.645	.000
2.	.050	22876.	.041	83.	.009	.033	.905	1.680	.007
3.	.050	22743.	.041	83.	.009	.034	.937	1.714	.014
4.	.050	22591.	.041	82.	.009	.034	.973	1.749	.020
5.	.050	22597.	.041	82.	.009	.035	.989	1.783	.027
6.	.050	22584.	.041	82.	.010	.035	1.000	1.818	.034
7.	.050	22633.	.041	82.	.010	.035	1.000	1.852	.040
8.	.050	22602.	.041	82.	.010	.035	1.000	1.886	.047
9.	.050	22500.	.041	82.	.010	.036	1.000	1.920	.054
10.	.050	22574.	.041	82.	.010	.036	1.000	1.954	.061
11.	.050	22603.	.041	81.	.010	.036	1.000	1.988	.068
12.	.050	22524.	.041	81.	.010	.037	1.000	2.022	.074
13.	5.550	22541.	.867	51.	.010	.037	1.000	2.056	.081
14.	3.890	22603.	.046	42.	.014	.052	1.000	2.915	.088
15.	3.830	22706.	.068	42.	.014	.051	1.000	2.954	.095
16.	3.720	22764.	.078	40.	.014	.051	1.000	3.015	.102
17.	3.576	22853.	.088	38.	.014	.051	1.000	3.085	.110
18.	3.398	22972.	.071	35.	.014	.050	1.000	3.166	.117
19.	3.243	23052.	.007	12.	.014	.050	1.000	3.229	.124
20.	3.235	22964.	.014	17.	.014	.050	1.000	3.228	.132
21.	3.204	22898.	.063	28.	.014	.050	1.000	3.234	.139
22.	3.029	22965.	.053	24.	.014	.049	1.000	3.289	.147
23.	2.862	23010.	.005	6.	.013	.049	1.000	3.334	.155
24.	2.825	22929.	.003	4.	.013	.049	1.000	3.332	.163
25.	2.786	22845.	.068	20.	.013	.048	1.000	3.327	.170
26.	2.503	22940.	.069	18.	.013	.048	1.000	3.388	.178
27.	2.175	23042.	.075	16.	.013	.048	1.000	3.449	.186
28.	1.766	23166.	.039	11.	.013	.048	1.000	3.516	.194
29.	1.466	23193.	.035	12.	.013	.047	1.000	3.547	.202
30.	1.223	23007.	.056	14.	.013	.047	1.000	3.574	.211
31.	.866	22834.	.019	8.	.013	.047	1.000	3.621	.219
32.	.668	22644.	.002	1.	.013	.046	1.000	3.632	.227
33.	.546	22447.	.029	9.	.013	.046	1.000	3.626	.236
34.	.274	22266.	.023	8.	.013	.046	1.000	3.647	.244
35.	.050	22084.	.037	73.	.013	.046	1.000	3.661	.252
36.	.050	21912.	.002	4.	.013	.045	1.000	3.690	.260
37.	.050	21723.	.000	0.	.012	.045	1.000	3.684	.268
38.	.050	21531.	.009	19.	.012	.045	1.000	3.669	.282
39.	.050	21350.	.039	79.	.012	.044	1.000	3.671	.291
40.	.050	21189.	.031	61.	.012	.044	1.000	3.702	.299
41.	.050	21022.	.000	0.	.012	.044	1.000	3.725	.307
42.	.050	20832.	.000	0.	.012	.044	1.000	3.700	.332
43.	.050	20653.	.000	0.	.012	.043	1.000	3.691	.340
44.	.050	20470.	.025	51.	.012	.043	1.000	3.671	.361
45.	.050	20309.	.026	52.	.012	.043	1.000	3.688	.368
46.	.050	20150.	.023	45.	.012	.042	1.000	3.706	.376
47.	.050	19992.	.010	20.	.012	.042	1.000	3.721	.384
48.	.050	19828.	.006	13.	.012	.042	1.000	3.724	.392
49.	.050	19664.	.001	1.	.012	.042	1.000	3.722	.400
50.	.050	19499.	.002	4.	.012	.041	1.000	3.715	.407
51.	.050	19337.	.000	0.	.012	.041	1.000	3.709	.415
52.	.050	19155.	.000	0.	.011	.041	1.000	3.668	.456
53.	.050	18969.	.000	0.	.011	.040	1.000	3.616	.508
54.	.050	18799.	.000	0.	.011	.040	1.000	3.589	.535
55.	.050	18638.	.011	22.	.011	.040	1.000	3.575	.549
56.	.050	18491.	.005	10.	.011	.040	1.000	3.578	.557
57.	.050	18341.	.000	0.	.011	.039	1.000	3.576	.564
58.	.050	18187.	.000	0.	.011	.039	1.000	3.564	.576
59.	.050	18038.	.000	0.	.011	.039	1.000	3.556	.584
60.	.050	17882.	.000	0.	.011	.038	1.000	3.536	.604
61.	.050	17713.	.000	0.	.011	.038	1.000	3.494	.646
62.	.050	17540.	.000	0.	.011	.038	1.000	3.443	.697
63.	.050	17384.	.000	0.	.011	.038	1.000	3.417	.723
64.	.050	17232.	.000	0.	.011	.037	1.000	3.395	.746
65.	.050	17076.	.000	0.	.010	.037	1.000	3.363	.777
66.	.050	16932.	.000	0.	.010	.037	1.000	3.348	.792
67.	.050	16784.	.000	0.	.010	.036	1.000	3.324	.816
68.	.050	16646.	.000	0.	.010	.036	1.000	3.314	.826
69.	.050	16505.	.000	0.	.010	.036	1.000	3.298	.842
70.	.050	16362.	.000	0.	.010	.036	1.000	3.275	.865
71.	.050	16216.	.000	0.	.010	.035	1.000	3.247	.894

File : AEF881W.OUT

Arrhenatherum elatius ; fertilized/till 1st cut ; 1988.
Mixed culture.
All weights are expressed in g DM/m2.

TIME	WRT	WLV	WST	WER	WDRT	WDLV	WSH	WLB	WTOT
1.	52.7	10.1	3.5	.0	52.7	18.0	13.6	66.3	137.0
2.	52.5	10.1	3.6	.0	53.2	18.1	13.7	66.2	137.5
3.	52.5	10.3	3.7	.0	53.8	18.3	14.0	66.5	138.5
4.	52.4	10.4	3.8	.0	54.3	18.4	14.2	66.6	139.3
5.	53.1	11.1	4.0	.0	54.8	18.6	15.1	68.2	141.6
6.	53.7	11.6	4.2	.0	55.3	18.7	15.8	69.5	143.6
7.	54.5	12.3	4.5	.0	55.9	18.9	16.8	71.3	146.1
8.	54.9	12.7	4.6	.0	56.4	19.1	17.3	72.3	147.8
9.	55.0	12.9	4.7	.0	57.0	19.3	17.6	72.6	148.8
10.	55.8	13.6	5.0	.0	57.5	19.5	18.6	74.4	151.4
11.	56.4	14.1	5.2	.0	58.1	19.7	19.3	75.7	153.4
12.	56.5	14.3	5.3	.0	58.6	19.9	19.6	76.1	154.6
13.	56.9	14.7	5.5	.0	59.2	20.1	20.2	77.2	156.5
14.	57.5	15.3	5.7	.0	59.8	20.3	21.0	78.5	158.6
15.	58.7	16.1	6.0	.0	60.3	20.5	22.2	80.9	161.8
16.	58.7	17.5	7.4	.0	60.9	20.8	24.9	83.5	165.3
17.	58.7	19.1	9.0	.0	61.5	21.1	28.1	86.8	169.4
18.	58.8	21.1	10.9	.0	62.1	21.3	32.1	90.9	174.4
19.	59.0	23.1	12.8	.0	62.7	21.7	35.9	94.9	179.3
20.	58.8	23.9	13.8	.0	63.3	22.0	37.7	96.5	181.8
21.	58.6	24.9	15.0	.0	63.9	22.4	39.9	98.5	184.8
22.	58.9	27.3	17.3	.0	64.5	22.7	44.6	103.5	190.7
23.	59.3	29.7	19.7	.0	65.0	23.1	49.3	108.6	196.8
24.	59.2	30.9	21.1	.0	65.6	23.6	52.0	111.3	200.5
25.	59.2	32.2	22.6	.0	66.2	24.1	54.9	114.1	204.4
26.	60.0	36.1	26.3	.0	66.8	24.5	62.4	122.4	213.8
27.	61.1	40.6	30.6	.0	67.4	25.1	71.2	132.3	224.8
28.	62.5	46.2	35.9	.0	68.0	25.7	82.1	144.6	238.3
29.	63.6	50.8	40.4	.0	68.7	26.4	91.2	154.8	249.8
30.	63.6	52.5	48.3	.7	69.3	27.1	101.5	165.0	261.5
31.	63.7	54.9	58.6	1.6	69.9	27.9	115.1	178.8	276.7
32.	63.6	56.4	66.1	2.3	70.6	28.8	124.7	188.3	287.6
33.	63.4	57.4	72.1	2.8	71.2	29.6	132.3	195.7	296.5
34.	63.4	59.4	81.3	3.6	71.8	30.5	144.3	207.8	310.1
35.	63.5	61.3	90.5	4.4	72.5	31.4	156.2	219.7	323.5
36.	63.7	63.9	101.8	5.4	73.1	32.3	171.2	234.9	340.2
37.	63.6	65.3	109.4	6.1	73.7	33.2	180.7	244.3	351.3
38.	63.5	66.4	116.1	6.7	74.4	34.2	189.2	252.6	361.2
39.	63.5	68.2	125.4	7.5	75.0	35.2	201.1	264.6	374.8
40.	63.9	71.8	140.1	8.8	75.7	36.2	220.6	284.6	396.4
41.	64.3	74.9	153.8	10.0	76.3	37.3	238.7	303.1	416.6
42.	64.2	75.9	160.5	10.6	76.9	38.4	246.9	311.1	426.5
43.	64.3	77.8	170.4	11.5	77.6	39.6	259.6	323.9	441.0
44.	64.2	79.1	178.5	12.2	78.2	40.7	269.8	334.0	452.9
45.	64.8	82.9	194.6	13.6	78.9	41.9	291.2	355.9	476.7
46.	65.4	87.1	212.4	15.2	79.5	43.2	314.7	380.1	502.8
47.	66.1	91.6	231.0	16.8	80.2	44.5	339.4	405.5	530.1
48.	66.6	95.1	246.8	18.2	80.8	45.8	360.1	426.7	553.3
49.	67.1	98.3	261.9	19.5	81.5	47.3	379.8	446.8	575.6
50.	67.4	101.2	275.9	20.8	82.2	48.7	397.8	465.3	596.2
51.	67.9	101.0	292.7	23.9	82.8	50.3	417.7	485.6	618.7
52.	67.6	100.0	298.5	25.0	83.5	51.8	423.5	491.1	626.4
53.	67.1	98.6	300.9	25.4	84.2	53.3	425.0	492.1	629.5
54.	67.0	97.9	310.5	27.2	84.9	54.8	435.6	502.6	642.3
55.	67.2	97.5	323.7	29.7	85.5	56.2	451.0	518.2	660.0
56.	67.8	97.5	341.6	33.0	86.2	57.7	472.1	539.9	683.8
57.	68.1	97.3	357.1	35.9	86.9	59.2	490.3	558.4	704.5
58.	68.3	96.8	369.4	38.2	87.6	60.6	504.4	572.6	720.8
59.	68.5	96.4	382.5	40.7	88.2	62.1	519.6	588.0	738.3
60.	68.4	95.7	392.0	42.5	88.9	63.5	530.2	598.6	751.0
61.	68.0	94.6	395.8	43.2	89.6	64.9	533.5	601.5	756.1
62.	67.4	93.3	397.4	43.5	90.3	66.4	534.2	601.6	758.2
63.	67.2	92.5	404.8	44.8	91.0	67.8	542.2	609.4	768.1
64.	67.1	91.8	413.1	46.4	91.6	69.1	551.3	618.4	779.2
65.	66.8	90.8	418.9	47.5	92.3	70.5	557.2	624.1	786.9
66.	66.8	90.3	428.6	49.3	93.0	71.9	568.1	634.9	799.8
67.	66.6	89.5	436.0	50.7	93.6	73.2	576.1	642.7	809.6
68.	66.6	89.0	446.3	52.6	94.3	74.6	587.8	654.4	823.3
69.	66.5	88.3	454.9	54.2	95.0	75.9	597.4	664.0	834.9
70.	66.3	87.6	461.8	55.5	95.6	77.2	604.9	671.2	844.1
71.	66.1	86.7	467.5	56.5	96.3	78.6	610.7	676.8	851.6

File : FRF881W.OUT

Festuca rubra ; fertilized/till 1st cut ; 1988.
Mixed culture.
All weights are expressed in g DM/m2.

TIME	WRT	WLV	WST	WER	WDRT	WDLV	WSH	WLB	WTOT
1.	106.3	19.5	6.1	.0	106.3	46.3	25.6	132.0	284.6
2.	105.5	19.4	6.2	.0	107.4	46.6	25.6	131.1	285.1
3.	104.9	19.4	6.3	.0	108.5	46.9	25.7	130.6	286.0
4.	104.2	19.4	6.4	.0	109.5	47.2	25.8	130.0	286.7
5.	104.2	19.9	6.7	.0	110.6	47.5	26.6	130.8	288.8
6.	104.2	20.3	7.0	.0	111.6	47.8	27.2	131.4	290.8
7.	104.4	20.9	7.3	.0	112.6	48.1	28.2	132.6	293.3
8.	104.2	21.2	7.6	.0	113.7	48.4	28.8	133.0	295.1
9.	103.8	21.3	7.7	.0	114.7	48.7	29.0	132.8	296.3
10.	104.1	22.0	8.1	.0	115.8	49.0	30.1	134.2	299.0
11.	104.2	22.5	8.4	.0	116.8	49.4	31.0	135.2	301.4
12.	103.9	22.7	8.6	.0	117.9	49.7	31.3	135.2	302.7
13.	104.0	23.1	8.9	.0	118.9	50.0	32.1	136.0	305.0
14.	104.2	23.7	9.3	.0	119.9	50.4	33.1	137.3	307.6
15.	104.7	24.5	9.7	.0	121.0	50.7	34.2	138.9	310.6
16.	105.0	25.7	10.1	.0	122.0	51.1	35.8	140.8	313.9
17.	105.4	27.2	10.4	.0	123.1	51.5	37.6	143.0	317.6
18.	105.9	28.8	10.8	.0	124.1	51.9	39.6	145.6	321.6
19.	106.3	30.1	11.2	.0	125.2	52.3	41.3	147.6	325.1
20.	105.9	30.5	11.4	.0	126.2	52.8	41.9	147.8	326.8
21.	105.6	31.0	11.5	.0	127.3	53.2	42.5	148.1	328.7
22.	105.9	32.2	11.9	.0	128.4	53.7	44.1	150.0	332.1
23.	106.1	33.3	12.2	.0	129.4	54.2	45.5	151.7	335.3
24.	105.8	33.7	12.4	.0	130.5	54.7	46.1	151.8	337.0
25.	105.4	34.0	12.5	.0	131.5	55.2	46.6	151.9	338.7
26.	105.8	35.4	12.9	.0	132.6	55.7	48.3	154.1	342.4
27.	106.3	36.8	13.3	.0	133.7	56.2	50.1	156.3	346.2
28.	106.8	38.3	13.7	.0	134.7	56.8	52.0	158.8	350.3
29.	107.0	39.2	14.0	.0	135.8	57.4	53.2	160.1	353.3
30.	106.1	39.5	15.0	.4	136.9	57.9	55.0	161.1	355.9
31.	105.3	40.1	16.3	1.0	137.9	58.5	57.4	162.7	359.2
32.	104.4	40.3	17.2	1.4	139.0	59.1	58.9	163.3	361.4
33.	103.5	40.3	17.8	1.7	140.0	59.7	59.8	163.4	363.1
34.	102.7	40.6	18.8	2.1	141.0	60.3	61.5	164.2	365.6
35.	101.9	40.9	19.7	2.5	142.1	61.0	63.1	165.0	368.0
36.	101.1	41.3	20.8	3.0	143.1	61.6	65.1	166.1	370.8
37.	100.2	41.3	21.5	3.3	144.1	62.2	66.0	166.2	372.5
38.	99.3	41.2	22.1	3.5	145.1	62.8	66.8	166.1	374.0
39.	98.5	41.3	22.9	3.9	146.1	63.4	68.0	166.5	376.0
40.	97.7	41.7	24.0	4.4	147.1	64.0	70.1	167.8	379.0
41.	97.0	42.0	25.0	4.8	148.1	64.7	71.9	168.8	381.6
42.	96.1	41.8	25.5	5.0	149.0	65.3	72.3	168.4	382.8
43.	95.3	41.8	26.2	5.3	150.0	65.9	73.3	168.5	384.4
44.	94.4	41.7	26.7	5.5	150.9	66.6	73.9	168.3	385.8
45.	93.7	42.0	27.7	6.0	151.9	67.2	75.6	169.2	388.3
46.	92.9	42.2	28.7	6.4	152.8	67.8	77.3	170.2	390.9
47.	92.2	42.5	29.6	6.8	153.8	68.4	79.0	171.2	393.4
48.	91.5	42.6	30.4	7.2	154.7	69.1	80.2	171.7	395.4
49.	90.7	42.7	31.2	7.5	155.6	69.7	81.4	172.1	397.4
50.	89.9	42.7	31.9	7.8	156.5	70.4	82.4	172.3	399.2
51.	89.2	42.8	32.8	8.0	157.4	71.0	83.5	172.7	401.1
52.	88.3	42.5	33.1	8.0	158.3	71.6	83.5	171.9	401.8
53.	87.5	41.9	33.2	8.0	159.2	72.3	83.1	170.6	402.1
54.	86.7	41.8	33.7	8.1	160.0	72.9	83.6	170.3	403.2
55.	86.0	41.8	34.4	8.3	160.9	73.5	84.4	170.4	404.8
56.	85.3	42.0	35.4	8.4	161.8	74.2	85.8	171.1	407.0
57.	84.6	42.2	36.3	8.6	162.6	74.8	87.1	171.7	409.1
58.	83.9	42.3	37.0	8.7	163.5	75.4	88.0	171.9	410.8
59.	83.2	42.4	37.8	8.9	164.3	76.1	89.1	172.3	412.6
60.	82.5	42.3	38.4	9.0	165.1	76.7	89.7	172.2	414.0
61.	81.7	41.9	38.7	9.0	166.0	77.3	89.6	171.3	414.6
62.	80.9	41.4	38.8	9.1	166.8	78.0	89.2	170.1	414.9
63.	80.2	41.2	39.3	9.1	167.6	78.6	89.6	169.8	416.0
64.	79.5	41.1	39.9	9.3	168.4	79.2	90.2	169.7	417.3
65.	78.8	40.8	40.3	9.3	169.2	79.8	90.4	169.2	418.2
66.	78.1	40.8	40.9	9.4	170.0	80.4	91.2	169.3	419.7
67.	77.4	40.7	41.5	9.5	170.8	81.0	91.7	169.2	420.9
68.	76.8	40.8	42.2	9.7	171.5	81.6	92.7	169.5	422.7
69.	76.1	40.8	42.9	9.8	172.3	82.3	93.5	169.6	424.2
70.	75.5	40.7	43.4	9.9	173.1	82.9	94.0	169.5	425.4
71.	74.8	40.5	43.9	10.0	173.8	83.5	94.4	169.1	426.4

File : CHECK.OUT

This file contains the check variables of all species.
First column : TIME
NS columns : CHKLAI(1) .... CHKLAI(NS)
one column : CHKRAD
NS columns : CHKWTT(1) .... CHKWTT(NS)
one column : CHKNIT

1.	.0E+00	.0E+00	.0E+00	.0E+00	.0E+00	.0E+00
2.	.0E+00	.0E+00	.0E+00	.1E-04	-.5E-05	-.2E-05
3.	.0E+00	.0E+00	.0E+00	.6E-05	-.5E-05	.7E-05
4.	.0E+00	-.7E-05	.0E+00	.1E-04	-.1E-04	.7E-05
5.	.0E+00	.0E+00	.0E+00	.2E-04	-.1E-04	-.2E-05
6.	.0E+00	.0E+00	.0E+00	.1E-04	-.5E-05	-.1E-04
7.	.6E-05	.0E+00	.0E+00	.1E-04	.0E+00	.7E-05
8.	-.6E-05	.0E+00	.0E+00	.1E-04	-.5E-05	-.2E-05
9.	-.6E-05	.0E+00	.0E+00	.5E-05	.0E+00	-.1E-04
10.	.0E+00	.0E+00	.0E+00	.5E-05	.0E+00	-.2E-05
11.	.0E+00	.1E-04	.0E+00	.5E-05	.0E+00	-.1E-05
12.	.0E+00	.0E+00	.0E+00	.0E+00	.0E+00	-.9E-05
13.	.0E+00	.0E+00	.0E+00	-.5E-05	.5E-05	-.8E-05
14.	.0E+00	.0E+00	.0E+00	-.5E-05	.5E-05	-.1E-04
15.	.0E+00	.0E+00	.0E+00	-.9E-05	.5E-05	-.8E-05
16.	.0E+00	.0E+00	.0E+00	-.5E-05	.0E+00	-.3E-05
17.	.0E+00	.8E-05	.0E+00	-.5E-05	.5E-05	.0E+00
18.	.0E+00	.0E+00	.0E+00	-.9E-05	.0E+00	-.1E-04
19.	.0E+00	.0E+00	.0E+00	-.4E-05	-.9E-05	-.5E-05
20.	.0E+00	.0E+00	.0E+00	.0E+00	-.1E-04	-.8E-05
21.	.0E+00	.0E+00	.0E+00	-.4E-05	-.1E-04	-.5E-05
22.	.0E+00	.0E+00	.0E+00	-.4E-05	-.9E-05	.0E+00
23.	.0E+00	.0E+00	-.8E-05	-.4E-05	-.5E-05	-.5E-05
24.	.0E+00	.0E+00	.0E+00	.0E+00	-.9E-05	-.3E-05
25.	.0E+00	.0E+00	.0E+00	.0E+00	-.9E-05	-.3E-05
26.	.0E+00	.0E+00	-.6E-05	.0E+00	-.1E-04	-.1E-04
27.	.0E+00	.0E+00	.1E-04	.0E+00	-.9E-05	-.8E-05
28.	.0E+00	.0E+00	.6E-05	.3E-05	-.4E-05	-.9E-05
29.	.0E+00	.0E+00	-.6E-05	.0E+00	-.1E-04	-.1E-04
30.	.0E+00	.0E+00	-.1E-04	-.3E-05	-.1E-04	-.5E-05
31.	.0E+00	.0E+00	-.7E-05	-.3E-05	-.1E-04	-.9E-05
32.	.0E+00	.0E+00	.9E-05	-.5E-05	-.1E-04	-.7E-05
33.	.0E+00	.0E+00	.0E+00	-.1E-04	-.2E-04	-.1E-04
34.	-.8E-05	.0E+00	.0E+00	-.1E-04	-.2E-04	-.2E-04
35.	.0E+00	.0E+00	.0E+00	-.1E-04	-.2E-04	-.2E-04
36.	.7E-05	.0E+00	-.7E-05	-.1E-04	-.2E-04	-.2E-04
37.	.0E+00	.0E+00	-.8E-05	-.9E-05	-.8E-05	-.2E-04
38.	-.7E-05	.0E+00	.0E+00	-.8E-05	-.1E-04	-.2E-04
39.	.0E+00	.0E+00	.7E-05	-.8E-05	-.2E-04	-.3E-04
40.	.0E+00	.0E+00	-.2E-04	-.4E-05	-.2E-04	-.2E-04
41.	.0E+00	.0E+00	.8E-05	-.7E-05	-.2E-04	-.2E-04
42.	.0E+00	.0E+00	.1E-04	-.7E-05	-.2E-04	-.8E-05
43.	.0E+00	.0E+00	.0E+00	-.5E-05	-.2E-04	-.2E-04
44.	.0E+00	.0E+00	.0E+00	-.3E-05	-.2E-04	-.2E-04
45.	.0E+00	.0E+00	.0E+00	-.6E-05	-.3E-04	-.2E-04
46.	.0E+00	.0E+00	.0E+00	-.9E-05	-.3E-04	-.2E-04
47.	.0E+00	.0E+00	.0E+00	-.3E-05	-.3E-04	-.3E-04
48.	.0E+00	.0E+00	.0E+00	-.6E-05	-.3E-04	-.2E-04
49.	-.8E-05	-.1E-04	.0E+00	-.1E-04	-.3E-04	-.2E-04
50.	.0E+00	.0E+00	.0E+00	-.1E-04	-.3E-04	-.2E-04
51.	.0E+00	.0E+00	.0E+00	-.1E-04	-.3E-04	-.3E-04
52.	.0E+00	.0E+00	.0E+00	-.1E-04	-.3E-04	-.3E-04
53.	.0E+00	.0E+00	.0E+00	-.1E-04	-.3E-04	-.2E-04
54.	.0E+00	.0E+00	.7E-05	-.2E-04	-.4E-04	-.7E-05
55.	.0E+00	.0E+00	.0E+00	-.2E-04	-.4E-04	-.2E-04
56.	.0E+00	.0E+00	.0E+00	-.2E-04	-.4E-04	-.2E-04
57.	.0E+00	.0E+00	.0E+00	-.2E-04	-.4E-04	-.2E-04
58.	.0E+00	.0E+00	-.7E-05	-.2E-04	-.3E-04	-.2E-04
59.	.0E+00	.0E+00	.0E+00	-.2E-04	-.3E-04	-.2E-04
60.	.0E+00	.0E+00	.0E+00	-.3E-04	-.3E-04	-.2E-04
61.	.0E+00	.0E+00	.7E-05	-.2E-04	-.4E-04	-.2E-04
62.	.0E+00	.0E+00	.0E+00	-.2E-04	-.4E-04	-.2E-04
63.	.0E+00	.0E+00	-.1E-04	-.2E-04	-.4E-04	-.2E-04
64.	.0E+00	.0E+00	.0E+00	-.3E-04	-.5E-04	-.2E-04
65.	.0E+00	.0E+00	.0E+00	-.2E-04	-.4E-04	-.2E-04
66.	.0E+00	.0E+00	.0E+00	-.2E-04	-.4E-04	-.2E-04
67.	.0E+00	.0E+00	.0E+00	-.2E-04	-.4E-04	-.2E-04
68.	.0E+00	.0E+00	.0E+00	-.3E-04	-.4E-04	-.2E-04
69.	.0E+00	.0E+00	.0E+00	-.2E-04	-.4E-04	-.2E-04
70.	.0E+00	.0E+00	.8E-05	-.2E-04	-.4E-04	-.1E-04
71.	.0E+00	.0E+00	.0E+00	-.3E-04	-.4E-04	-.1E-04