PLANT NUTRIENT PARAMETERS

The **GLEAMS** plant nutrient component simulates nitrogen fixation by legumes during nitrogen-deficient periods. Also, **GLEAMS** represents land application of animal waste by creating organic ammonia, nitrogen, and phosphorus pools for mineralization. Organic N and P represent the portion that mineralizes at a higher rate than for active soil mineralizable nitrogen and phosphorus. A portion of the animal waste mineralizes to the active soil mineralizable N and P pools. The same is true for crop residue in the soil as well.

Input of nutrient parameters for initialization of pools is minimized by using soil horizon data and the model distributes the values into the appropriate computational layers. If soil nutrient data are available for local conditions (soils), the model user should input those values. If data are not available, generalized estimates can be generated by the model. <u>DO NOT USE THE ESTIMATES AND COMPARE MODEL RESULTS WITH OBSERVED DATA FROM FIELD EXPERIMENTS</u>. That will only result in comparing generalizations with a specific field, and they won't fit.

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<u>Cards 1 to 3</u>: **TITLE**

TITLE Three 80-character lines of alphanumeric information that identifies the particular computer run. For example, the soil type, the crop rotation, the tillage practices, may be useful in identifying the file. This title will be reproduced on the nutrient output file.

<u>Card 4</u>: **NBYR*, NEYR*, NUTOUT, FLGROT, FLGBAL**

NBYR Beginning year of plant nutrient simulation, (four digits), e.g. 1936

NEYR Ending year of plant nutrient simulation, (four digits), e.g. 1985

NUTOUT Code to designate level of printed nutrient output:

- 0 for annual summaries only,
- 1 for monthly and annual summaries,
- 2 for storm output, and monthly & annual summaries,
- 3 for storm output with concentrations by layer, and monthly and annual summaries.

Caution: NUTOUT = 3 generates much printout; use sparingly!

FLGROT Number of years in a rotation cycle. Use 1 for a continuous crop (mono-culture). If a 7-year study was conducted for which **GLEAMS** is to be applied, and a different crop was planted each year or at least there was not a regular crop sequence, **FLGROT** would be 7.

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[*] Changed in version 3.0 to 4-digit year for Y2K compliance.

FLGBAL Code for output of N and P balance at the end each year of simulation.

0 No N & P balance output,
1 Output N & P balance each year.

Card 5: **RESDW, RCN, CNI, CPI**

RESDW Crop residue, kg/ha, on the ground surface when simulation begins, e.g. 550.0

RCN Nitrogen concentration in rainfall, ppm, e.g. 1.2

CNI Concentration of nitrate-nitrogen in irrigation, ppm, e.g. 5.0

CPI Concentration of labile-phosphorus in irrigation, ppm, e.g. 1.2

Card 6: **TN(J)** for J=1 to **NOSOHZ** (card 6 in hydrology)

TN() Total nitrogen, percent, in soil horizon J, e.g. 1.35

Card 7: **CNIT(J)** for J = 1 to **NOSOHZ** (card 6 in hydrology)

CNIT() Nitrate-nitrogen concentration, µg/g (ppm), in soil horizon J, e.g. 20.0

Card 8: **POTMN(J)** for J = 1 to **NOSOHZ** (card 6 hydrology)

POTMN() Potentially mineralizable nitrogen, kg/ha, in the soil horizon, e.g. 130.0

Card 9: **ORGNW**

ORGNW Organic nitrogen content from animal waste, %,in the plow horizon, e.g. 0.40

Card 10: **TP(J)** for J = 1 to **NOSOHZ** (card 6 in hydrology)

TP() Total phosphorus, percent, in the soil horizon, e.g. 0.25

Card 11: **CLAB(J)** for J = 1 to **NOSOHZ** (card 6 in hydrology)

CLAB() Labile phosphorus concentration, μg/g (ppm), in the soil horizon, e.g. 10.0

Card 12: **ORGPW**

ORGPW Organic phosphorus content from animal waste, %, in the plow horizon, e.g. 0.10

NOTE: If local data are not available for initializing all parameters on cards 6-12, it can be done internally in the model IF you are willing to accept default values. To use default values, insert a blank line for the missing parameter. Enter those data available on the appropriate lines and leave the remaining lines blank. For example, if total nitrogen (**TN**) and labile phosphorus (**CLAB**) are available, enter the values on cards 6 and 11, respectively, and leave cards 7-10 and card 12 blank.

Updatable plant nutrient input begins with card 13. The following parameters relate to management practices that change from crop to crop, and must be updated externally. These include fertilizer application, animal waste application, and tillage. Although tillage is included in the erosion component, it is impor-tant here for incorporation or injection of fertilizer and animal waste.

Card 13: **PDATE**

PDATE Date that the following parameters are valid, year of the rotation cycle and Julian day, e.g. 1091

Card 13 is the last card in a nutrient parameter file with **PDATE** = 0.

Card 14: **NF, NTIL, DHRVST**

NF Number of fertilizer and animal waste applications, during the update period, generally from the day after harvest of one crop (or plow-down of weeds, cover crop, or crop residue) to harvest of the next crop, e.g. 4

NTIL Number of tillage operations during the update period, e.g. 5

DHRVST Date of crop harvest, year of the rotation cycle and Julian day, e.g. 1274

Card 15: **ICROP, LEG, PY, DMY, CNR, RNP, C1, C2**

ICROP Identification number of the crop grown during this cropping period, e.g. 7

NOTE: **ICROP** must correspond with those in the Table N-2. It is used as a subscript to access **PY**, **DMY**, **CNR**, **RNP**, **C1**,and **C2**.

LEG Code for legume crop, e.g. 1

0 not a legume crop
1 legume crop

If **ICROP** < 79, **LEG** can be left blank since it is specified in the model for those crops listed in the appendix. If **ICROP** > 78, **LEG** must be input here.

PY Potential yield, kg/ha, for the harvestable portion of the crop, e.g. 45000.0

Corn grain yield might be 9400.0 (150 bu.), but corn silage might be 56000 (25 tons). If the default (Table N-2) value is accepted, leave **PY** blank. Otherwise, enter the value. If a green manure crop or one of the crops in Table N-2 is not harvested but plowed under or left standing,

PY should be the potential total dry matter including roots. Do not use **PY** from Table N-2 unless you estimate that value as the potential total dry matter.

DMY Dry matter ratio, the ratio of total dry matter production to harvestable portion of the crop, e.g. 2.5

If **ICROP** < 79, **DMY** can be left blank. If **ICROP** < 79, and it is not harvested, such as rye winter cover or final growth of alfalfa after seed harvest that is plowed under in the following spring, set **DMY** = **-**1.0. The negative value indicates there is not a portion of the dry matter removed by harvest, and the 1.0 indicates the total biomass is returned to soil and residue.

CNR Carbon:nitrogen ratio for the crop, e.g. 80.0

If **ICROP** < 79, **CNR** can be left blank.

RNP Ratio of crop nitrogen to phosphorus, e.g. 7.6

If **ICROP** < 79, **RNP** can be left blank.

C1 Coefficient in the exponential relation to estimate nitrogen content of the crop, e.g. 1.60

If **ICROP** < 79, **C1** can be left blank.

C2 Exponent in the exponential relation to estimate nitrogen content of the crop, e.g. -0.247

If **ICROP** < 79, **C2** can be left blank.

Card 16: **DF, MFERT, METHAP, MTYPE**

DF Date of fertilizer application, e.g. 1121
The first digit indicates the year of the rotation, and the 121 is the Julian day of the year.

MFERT Code for method of fertilization:

0 for inorganic (commercial) fertilizer;
1 for organic (animal waste or sewage sludge).

METHAP Code for method of application:

0 for surface application of manure solids or slurry, or inorganic fertilizer;
1 for incorporated fertilizer or animal waste;
2 for injected (such as anhydrous ammonia or animal waste slurry).
3 fertigation
4 liquid animal waste (such as sprinkler-applied lagoon effluent)

MTYPE Code for animal waste type.

Leave blank if **MFERT** = 0

The animal waste type corresponds to those in Table N-3 where the default values are given for the waste characteristics. If the default values are not used, then the code for **MTYPE** should be 15. Table values generally represent fresh manure without bedding and applied directly without storage and leaching losses. Storage may be included for specific management practices.

1	beef cattle, solid
2	dairy cattle, solid
3	horse, solid
4	municipal sludge
5	poultry, solid
6	sheep, solid
7	swine, solid
8	beef, slurry
9	dairy, slurry
10	swine, slurry
11	beef, liquid
12	dairy, liquid
13	poultry, liquid
14	swine, liquid
15	if user is to supply total N and P, organic N and P, ammonia and soluble phosphorus.

Card 17: **FN, FNH, FP, DEPIN, FRTWAT**

Card 17 is used only for inorganic fertilizer application (**MFERT** = 0 on card 16). Skip card 17 for animal waste application. Do not leave a blank line.

FN Fertilizer nitrate, kg/ha, e.g. 115.0

(See Table N-4 for common fertilizer analysis.)

FNH Fertilizer ammonia, kg/ha, e.g. 60.0

(See Table N-4 for common fertilizer analysis.)

FP Fertilizer phosphorus, kg/ha, e.g. 45.0

(See Table N-4 for common fertilizer analysis.)

DEPIN Depth of incorporation, cm, e.g. 1.0

For surface application and fertigation (**METHAP** = 0 or 3 on card 16), use 0.0

FRTWAT Depth of water applied for fertigation, cm, e.g. 0.50

Leave blank for all other fertilizer applications.

Card 18: **RATE, DEPIN, ATN, APORGN, ANH, APHOS, APORGP, AOM, WASTYP**

Card 18 is used only for animal waste application (**MFERT** = 1, card 16). If inorganic fertilizer is applied, skip card 18. Do not leave it blank.

RATE Application rate for animal waste: If liquid is applied, **RATE** is equivalent depth, cm, e.g. 0.50; If solid waste is applied, **RATE** is tn/ha, e.g. 8.5

DEPIN Depth of animal waste injection, cm, e. g. 10.0 If **METHAP** = 0, 1, or 4 (Card 16) use 0.0

If **MTYPE** = 15, **ATN, APORGN, ANH, APHOS, APORGP, AOM** must be specified by the user. If **MTYPE** < 15, the fields can be left blank.

ATN Total nitrogen, %, in animal waste, e.g. 1.45

APORGN Organic nitrogen content, %, in animal waste, e.g. 1.0

ANH Ammonia content, %, in animal waste, e.g. 0.075

APHOS Total phosphorus content, %, in animal waste, e.g. 1.50

APORGP Organic phosphorus content, %, in animal waste, e.g. 0.50

AOM Organic matter content, %, in animal waste, e.g. 7.0

WASTYP Waste type

1 solid
2 slurry
3 liquid

As many cards 16, 17, or cards 16, 18, are needed as **NF** on card 14. For example, if **NF** = 2, and inorganic fertilizer is used, there are cards 16 and 17 for the first application date, and another set of cards 16 and 17 for the second application date. If animal waste is applied on the first application date and a topdress inorganic fertilizer application is made on the second date, there would be cards 16 and 18 for the first date, and cards 16 and 17 for the second date.

Card 19: **NTDAY, LTIL, DTIL, EFFINC, FMIX**

NTDAY Date of tillage, year of rotation cycle plus the Julian day, e.g. 1205

LTIL Code to designate the tillage implement according to the list below, e.g. 1

The following codes correspond to those in Table N-5 which shows the default values for **EFFINC** and **FMIX**.

1	Anhydrous ammonia applicator	11	Disk hiller
2	Bedder (lister)	12	Disk plow
3	Burn	13	Disk plow–one way
4	Chisel	14	Do-all
5	Cultivator--field (Hoeme)	15	Drill–deep furrow (dempster)
6	Cultivator--row	16	Drill–small grain
7	Digger--peanut	17	Harrow–spike tooth
8	Digger--potato	18	Harrow–spring tooth
9	Disk harrow--offset	19	Moldboard plow
10	Disk harrow--tandem	20	Paraplow
21	Planter–in-row chisel	22	Planter--knife, disk, sweep

If this list does not include the equipment desired, the user can designate 23, 24, etc., for **LTIL**.

DTIL Depth of tillage, cm, e.g. 7.5

EFFINC Efficiency of incorporation of surface residue, e.g. 0.85

EFFINC can be left blank if **LTIL** = 1 to 22. If **LTIL** > 22, the user must specify **EFFINC**.

FMIX Tillage mixing efficiency, e.g. 0.05

FMIX can be left blank if **LTIL** = 1 to 20. If **LTIL** > 22, the user must specify **FMIX**.

A card 19 is needed for each major tillage operation that (a) applies or incorporates or injects fertilizer, (b) applies or incorporates animal waste, or (c) that has a significant effect on surface residue and its incorporation. As many cards 24 are required as the value of **NTIL** on card 14.

Each crop in a rotation cycle requires a set of cards 13-19. Generally the update covers a period less than a year, i. e. planting to harvest of an annual crop such as corn, peanuts, etc. The update period may carry over the end of a year for winter small grain, for example. There are several extreme management alternatives that can be represented: a 2-year meadow in rotation without harvest or grazing, continuous pasture or rangeland that is harvested (grazed) but not fertilized or tilled. Multiple cropping, such as with vegetable and/or field crops require several updates within a year.

The nutrient parameter file ends with a card 13 which has 0 for **PDATE**. This gives normal termination with all the summary output.

NUTRIENT PARAMETERS DESCRIPTION

The plant nutrient component of **GLEAMS** and the associated parameter values allow the user to make a generalized application with model-initialized parameters or very site-specific detailed user-defined initialization. This manual is intended to define the parameters and pools and aid the user in understanding what the parameters represent and their relative sensitivity.

Parameters include the initial values that the model updates internally on a daily basis, and those that are user updatable such as fertilizer and animal waste application, and tillage. Some parameters are "built in" the model to alleviate user input, but users may change the values to better represent their respective application where desired. The internal values are given in tables for user information in the best estimation of parameters.

Research scientists working in the general area of plant nutrition and crop production may have most of the data needed, and they can easily estimate the other parameters. **GLEAMS** was developed with those specialists in mind. However, water quality specialists who do not have site-specific data may not be able to estimate these initial parameters easily. Those specialists were considered in the model development process, also.

Initial Codes

NBYR, NEYR, FLGROT

The beginning (**NBYR**) and ending (**NEYR**) years of simulation and the number of years in a rotation allow the model to establish a dummy file to be created with updatable parameters that repeat each rotation cycle. It allows the user to develop a relatively short parameter file without unnecessary repetition. An extreme example would be a continuous annual crop, e.g. corn, in a no-till system with fertilizer applied at planting and a topdress application just ahead of tasseling. With the rotation feature, the user would only need 8 update cards for a 25- or a 50-year simulation is planting, harvesting, and fertilization are made the same day each year. Without the rotation feature, a 25-year simulation would require 175 cards, and a 50-year simulation would require 350 cards.

FLGROT is the length of rotation in years. If a historical study is represented where continuous corn was planted on different dates each year of a 10-year study, **FLGROT** would be 10. Multicropping of vegetables is another extreme. For example a tomato-tomato-squash-fallow multicropping system is repeated each year of simulation with the same planting/transplanting dates and dates of fertilization and tillage used, **FLGROT** would be 1. A winter wheat-fallow-sorghum rotation would have **FLGROT** = 3.

When simulating a forest (**FOREST** > 0, hydrology parameters card 4), **FLGROT** must be specified to represent different applications. For example, a 20-year simulation for pine may begin with the year of planting and the pine may not be harvested during the 20-year period. For this situation **FLGROT** = 20, and the potential, **PY** (discussed below) would be different for the first 5-8 years when the annual biomass production largely leveled out at some maximum value. **NYRFOR** = 0 in hydrology to indicate that the pine planting began the year that simulation started. If the crop code (**ICROP**) = 81 to represent the pine trees, in year 1 the potential yield (**PY**) might be 1,000 kg/ha. The harvest date (**DHRVST**) would be set as 21366, indicating the 21st year of the rotation on day 366 which is beyond the end of simulation. The second year representation would have **ICROP** = 81, **DHRVST** = 21366, and **PY** might be 2,000 kg/ha. In year 2, **ICROP** = 81, **DHRVST** = 21366, and **PY** might be 3,000 kg/ha. In year 3 **PY** could be 6,000 kg/ha and in year 4 10,000 kg/ha and year 5 15,000 kg/ha and each year thereafter could have 17,500 kg/ha and **DHRVST** = 21366 each year.

Another example might be a 20-yr simulation for pine without harvest during the simulation period, and simulation begins after 5 years of growth. Then **NYRFOR** = 5 in hydrology and **FLGROT** = 1 in plant nutrients.

The model uses the cumulative **PY** given above to obtain the approximate biomass of forest growth prior to beginning of simulation.

If the forest is harvested (logged) during the simulation period, then **FLGROT** = 20. The estimated **PY**, such as that above, for the 20-year period, and if clear cutting occurs on day 250 of the 20^{th} year, **DHRVST** = 20250 on each year's input. This will be discussed further under "Updateable Parameters".

NUTOUT

Separate output for each component of **GLEAMS** allows the user to select quite a range of output for each component separately without overtaxing the system. Different levels are needed for different purposes. For example, a long-term simulation with annual or monthly and annual summaries may be sufficient to assess the effects of different management practices, whereas detailed output of nutrient concentrations by soil computational layer may be desirable for nutrient component validation. Storm output may be needed to examine leachate concentrations exceeding drinking water standards. **NUTOUT** allows the user to select the appropriate information level. The following codes are designated for the various levels of output:

0 for annual summaries only,
1 for monthly and annual summaries,
2 for storm output, and monthly & annual summaries,
3 for storm output with concentrations by layer, and monthly and annual summaries.

NUTOUT = 3 generates considerable output, and this option should be used with caution. If concentration data by layer are needed for further analyses, it is recommended that the data be designated for selected variable output (**BCKEND**) in the hydrology options.

FLGBAL

The nutrient component has been verified and validated to give an annual balance of nitrogen and phosphorus of approximately zero considering rounding errors in the thousands of computations. However, the user may want to see how the different pools change from year-to-year such as soil nitrate, potentially mineralizable nitrogen, and labile phosphorus. By selecting output of the balance each year (**FLGBAL** = 1), the beginning and ending total mass in each pool in the root zone and on the surface is printed. The net balance is output, also.

Initial Parameters

Surface Residue--**RESDW**

Crop residue on the soil surface when simulation begins has two effects: (a) insulation effect on soil temperature, and (b) source of nitrogen and phosphorus mineralization. The best estimate is by weighing oven-dry residue samples from known size areas in the specific field of concern. This information probably is available where complete data for model validation, but it is obviously not available for long-term simulation beginning January 1, 1942. If the user is familiar with the general management practices in an area, a "clean till" or conventional tillage system may have little or no crop residue on the surface on January 1 if fall tillage is practiced. An estimated value **RESDW** = 0 would be valid for this system. An opposite extreme might be a no-till system for corn harvested in the fall, and **RESDW** = 7000 may represent an excellent management.

RESDW is calculated daily in **GLEAMS** to represent decay (mineralization) and additions due to crop harvest. The parameter is not sensitive in a long-term simulation, but may be very sensitive in short-term simulation of a low-input production system.

Rainfall Nitrogen, Irrigation Nitrogen and Phosphorus--**RCN, CNI, CPI**

Rainfall may be a significant source of nitrogen in some locations, particularly down wind from heavily industrialized areas. Chapin and Uttormark (1973) reported contributions in excess of 3 kg N/ha in the states bordering the Great Lakes. Rainfall nitrogen is mainly in the nitrate form, but it also includes ammonia. Concentrations vary during the year, and may considerably exceed the published values in some years.

Frere et al. (1980) used the combined nitrate and ammonia content reported in rainfall (Chapin and Uttormark, 1973) as nitrate input in **CREAMS**. Mineralization was considered as a one-step first-order process in **CREAMS**. Although ammonification and nitrification are considered as separate successive processes in **GLEAMS**, nitrification is a zero-order process. Therefore, the combined nitrate and ammonia in rainfall are considered as nitrate additions, and the map of Chapin and Uttormark (1973) is adapted for inclusion in this paper as Fig. N-1.

Values from the map of Fig. N-1 are entered for parameter **RCN**, ppm, for the specific field site. It is used as a constant in **GLEAMS** without change during the simulation period. **RCN** is not a sensitive parameter in **GLEAMS**.

In some locations, nitrogen and phosphorus in irrigation water are high enough to be taken into consideration in making fertilizer recommendations. Concentrations of 5 mg NO_3-N/L are not uncommon in areas where 40-50 cm of irrigation water is applied. This concentration would result in 20-25 kg NO_3-N/ha addition.

Contributions of nitrate-nitrogen and labile phosphorus in irrigation can be considered in **GLEAMS** by entering concentration of nitrate and phosphorus in irrigation, **CNI** and **CPI**, respectively. If the irrigation option, **IROPT** = 1, **CNI** and **CPI** will be used to automatically add nitrate-nitrogen and labile phosphorus with the model-applied irrigation. If irrigation amounts are included in the precipitation file for validation purposes, **IROPT** = 0, and **RCN** will be used to make nitrate additions.

CNI and **CPI** may not be readily available except where the respective concentrations are problems. Local values should be used, and if data are not available, model users should leave the parameters blank and additions will not be simulated. The model will not abnormally terminate if **IROPT** = 1, and **CNI** and **CPI** are left blank.

INITIALIZATION OF NITROGEN AND PHOSPHORUS POOLS

Short-term simulation requires the best estimates possible for initial nitrogen pools. This is especially true for validation comparisons with observed data. Because of the dynamicism of nitrate-nitrogen and ammonia-nitrogen, inaccurate initialization may not adversely affect the results of long-term simulation. Comparisons of management alternatives from long-term simulations are not sensitive to initialization of the pools. As described in Part I, the flow between the various pools prevent any one from becoming exceptionally large without compensation from one or more of the others.

Initial values of the different conceptualized pools are very site specific and are generally very management dependent. This is especially true for systems with animal waste application, those with intensive management such as high levels of fertility and production, and conservation tillage systems with heavy residue left on the soil surface. Model users are <u>strongly</u> urged to make every effort to obtain the best estimate possible for parameters, which may involve soil sampling and analyses.

Soil samples can be taken and laboratory analyses can be made to determine organic matter, total nitrogen, total phosphorus, nitrate, ammonia, and available phosphorus. However, total N and P includes these as well as the stable mineral N and P, which cannot be identified separately. If reliable data are not available, default values can be used. Soil pedon data such as that included in Soil Survey Investigation Reports (SSIR) by state, for example, Georgia (USDA, Soil Conservation Service, 1967) may contain total nitrogen content of each horizon as well as organic carbon. This information is not given for all pedons included in the SSIR's, and certainly all soils of interest in water quality are contained in the SSIR's. Another source of pedon data is publications by soil morphologists at the Land Grant Universities, for example, Perkins (1987). These publications result from assembling data from special studies and graduate theses. Pedon data are the next best source of information for parameter values to data from the specific field under investigation.

Generally soil data are determined by soil genetic horizon, i.e. pH, soil water characteristics, total kjeldahl nitrogen (TKN), etc. Since **GLEAMS** subdivides horizons into computational layers and all layers have the properties of the horizon, the model user is not required to enter data for each layer. Available data may include total N and total P only for the plow layer (surface or A_p horizon. If this is the case, and two or more horizons are designated for the simulation, the user can input the available data and the model will estimate that for the remaining horizons and parameters. By leaving blank fields (or lines) for missing data, the model initialization procedure will fill the gaps based upon the information and criteria below.

Nitrogen Parameters**--TN, CNIT, POTMN, ORGNW**

Total nitrogen, **TN**, is generally reported as TKN expressed as percent of the soil mass in a horizon. **TN** includes all forms of nitrogen except nitrate-nitrogen, i.e. mineralizable, stable organic, fresh organic, humus, ammonia, and etc. These so-called forms are conceptualized fractions, and **TN** actually includes **POTMN** and **ORGN**. If site-specific total nitrogen data are not available, the user can use data for the plow layer in Table N-1 taken from Stanford and Smith (1978). These data are given as total nitrogen unit mass (kg/ha) by soil order, and the user must convert them to percent by dividing by the unit soil mass in the plow layer. This is a straight-forward computation of multiplying the bulk density, BD, g/cm^3, by the thickness of the plow layer, TPL, cm, as

$$SOLMAS_p = (BD)_p \, (TPL)_p \, 10^5 \qquad [22]$$

where SOLMAS is soil mass, kg/ha, p is subscript to denote plow layer, and the constant, 10^5, is the net result of dividing 10^8 cm^2/ha by 10^3 g/kg.

If the data fields for **TN** are left blank in the parameter file, the model uses the organic matter content (**OM** entered in the hydrology parameter file) converted to organic carbon (OC) by dividing by 1.724 g **OM**/g OC, and dividing by the average carbon:nitrogen (C:N) ratio (10:1) for all soils given in Table N-1. This same procedure is used for other horizons if the **TN** fields are left blank. It certainly is not site-specific, but it makes a reasonable estimate.

Table N-1 can also be used to estimate potentially mineralizable nitrogen, **POTMN**, also. Just as for total nitrogen, **POTMN** is given in the table by soil order. Since Table N-1 is applicable for the surface horizon only, ratios of organic matter by horizon and ratios of horizon thickness can be used to estimate relative amounts (unit mass) of POTMN for other soil horizons.

If the fields for POTMN are left blank in the nutrient parameter file, estimates will be made in the model using organic matter content given by the relation from Smith et al. (1980)

$$POTMN_k = (SOLMAS_k) \, (OM_k) \, (9.3 \times 10^{-5}) \qquad [23]$$

where SOLMAS is soil mass, kg/ha, and **OM** is organic matter, percent.

Nitrate-nitrogen is very dynamic, and can be readily estimated, if data are not available, without sacrificing much accuracy in long-term simulation. It is much more sensitive when making short-term simulations or when a major event of interest occurs soon after simulation begins. If **CNIT** values are left blank in the parameter file, the model estimates concentrations of 10 µg NO_3-N/g of soil in all horizons. Because of the dynamic nature, transformations will rather quickly modify the values to more nearly represent actual conditions.

Organic nitrogen from animal waste application and incorporated in the plow layer prior to model simulation may be highly significant. If long-term animal waste application has been practiced, there may be considerable carry over from year-to-year. If inorganic fertilizer has been used entirely for N and P application in prior management systems, then it is obvious that organic N from waste in the plow layer would be zero. This is totally management dependent, and cannot be initialized internally. Since animal waste is only incorporated in the plow layer (A_p horizon), the user must estimate **ORGNW**, percent, for the top horizon. In warm moist climatic regions, such as the southern and southeastern U. S., only one-fourth of an annual application might be carried over, whereas as much as one-half might be carried over in cool moist regions or two-thirds in cold moist regions. The same logic might be applied for dry warm, dry cool, or dry cold regions where 50%, 60%, and 70%, respectively might apply. These are merely relative estimates for discussion, and local or state information should be used. **ORGNW** is a sensitive parameter since mineralization occurs as a first-order process.

Ammonia is not an input to the nutrient component, but included as one of the active pools. NH_4-N is estimated internally in the model as 2 µg/g of soil. The nitrification of NH_4-N is a zero-order process, and therefore it is very tran-sient with little sensitivity.

Root residue from previous crop production is estimated at the beginning of simulation as 40 kg/ha of mineralizable fresh organic nitrogen (FON) and distributed in the root zone.

The remaining nitrogen pool, stable mineral nitrogen (**SOILN**) is initialized internally by difference. As stated earlier, **TN** (or TKN) includes all forms of nitrogen except NO_3-N. Then **SOILN**, kg/ha, is estimated as

$$SOILN_i = \left[\frac{(TN_i)\ (SOLMAS_i)}{100} \right] - POTMN_i - ORGN_i - AMON_i - FON_i \qquad \textbf{[24]}$$

where **TN** is total nitrogen, percent, and **AMON** is NH_4-N, kg/ha, **ORGN** is organic nitrogen from animal waste, kg/ha, **POTMN** is active mineralizable soil nitrogen, kg/ha, FON is fresh organic nitrogen in crop residue (roots), and SOLMAS is soil mass in kg/ha. **SOILN** is not a sensitive parameter, and serves mainly as a buffer pool with interactive flow to and from the active mineral pool, **POTMN**.

Phosphorus Parameters--**TP, CLAB, ORGPW**

The discussion above for nitrogen initialization applies equally well for phosphorus, i. e. the best estimates are from the specific field site, or pedon data as first sources. Also as with nitrogen, data obtained from laboratory analyses of soil samples does not give a breakdown of all the various pools. Soil analysis for phosphorus is oftentimes limited to the plow layer since that is the depth of most concern. At best, only two phosphorus pools are included in data bases: total P (**TP**), and available or labile P (**CLAB**). Except at research locations, data include one but not both. In some rare instances, mineral P may be included in reports. Guidelines are given for estimating the phosphorus pools for **GLEAMS**, but users are strongly urged to obtain at least some of the data and not rely entirely on internal estimation procedures which give averages at best. The phosphorus pools in the soil that must be initialized include: fresh organic P in crop residue (FOP), organic humus P (SORGP), organic P from animal waste (**ORGPW**), plant-available or labile P (**CLAB**), the active mineral P (PMINP), and stable mineral P (SOILP). Total P is only an means to the end, and is the sum of all the pools except **CLAB**, similar to **TN** and **CNIT**.

State soil-testing laboratories analyze samples submitted by farmers or county extension agents, and generally send them only a phosphorus fertilizer recommendation for the field(s). Upon request, they will provide information on the phosphorus content of labile P as determined by some specific method of analysis, i. e. Olson, Bray, Mississippi, double acid, or etc. (McDowell et al., 1980; Sharpley et al., 1984). Each analysis gives slightly different results for what is described as "available P". Pedon data such as that of Perkins (1987) oftentimes show "available phosphorus", and the descriptive material of the publication gives the method by which the analysis was made.

Sharpley et al. (1984) related labile phosphorus, **CLAB**, µg/g, to Bray P (BP), Olson P (OP), and double acid P (DP) for three groups of soils: calcareous, slightly weathered, and highly weathered soils as designated by parameter **ISOIL** in hydrology. The relationships for calcareous soil are

$$\begin{aligned} CLAB = \; & 0.55\, BP + 6.1 \\ & 1.09\, OP + 3.2 \\ & 0.10\, DP + 10.2 \end{aligned} \qquad \textbf{[25]}$$

with coefficients of determination (R^2) of 0.83, 0.74, and 0.51, respectively.

For slightly weathered soils, Sharpley et al. (1984) gave

$$\begin{aligned} CLAB = \; & 0.56\, BP + 5.1 \\ & 1.07\, OP + 4.1 \\ & 0.13\, DP + 11.4 \end{aligned} \qquad \textbf{[26]}$$

with coefficients of determination of 0.79, 0.77, and 0.39, respectively.

Sharpley et al. (1984) gave relationships for highly weathered soils as

$$\begin{aligned} CLAB = \; & 0.14\, BP + 4.2 \\ & 0.55\, OP + 2.1 \\ & 0.24\, DP + 2.9 \end{aligned} \qquad \textbf{[27]}$$

with coefficients of determination of 0.76, 0.61, and 0.84, respectively.

The relationships of eqns. [4]-[6] can be used to estimate the labile P con-tent from available soil test results. If pedon data are used, and the method of analysis is not given, then "available phosphorus" must be assumed to be labile P as required in the model, i.e. **CLAB**.

Sharpley et al. (1984) used a considerable amount of data, and following works of others on limited data, related soil organic humus phosphorus (designated SORGP in this paper) to total nitrogen (**TN**) for the EPIC model (Sharpley and Williams, 1990). The relationship given by Sharpley et al. (1984) for the plow layer is

$$SORGP = 44.4 + 1130\, TN \qquad \textbf{[28]}$$

where SORGP is soil organic humus P, µg/g, and **TN** is total nitrogen, percent. The coefficient of determination was 0.64. Sharpley et al. (1984) considered adding soil pH to the relation, but it did not result in a better R^2.

For other soil horizons, Sharpley et al. (1984) gave the relation

$$SORGP = 1464\ TN \qquad \textbf{[29]}$$

with a coefficient of determination of 0.75. Equations [7] and [8] are included in **GLEAMS** to initialize the soil organic humus phosphorus pool.

In their extensive study of nitrogen and phosphorus properties of soils, Sharpley et al. (1984), gave values of SORGP and **CLAB** for calcareous, slightly weathered, and highly weathered soils. For calcareous soils, they found mean **CLAB** is about 10% of SORGP. **CLAB** is about 8.7% of SORGP for slightly weathered soils, and 5.6% for highly weathered soils. This provides an alternate method of estimating **CLAB**, and is included in **GLEAMS** if **CLAB** is left blank. This obviously is the least desirable estimate of labile phosphorus.

The organic P in animal waste, **ORGPW**, must be estimated for the plow layer if the model user wants to consider waste application prior to the beginning of simulation. It is management and climate dependent just as that for **ORGNW**. The user is referred to the discussion of **ORGNW** for estimating **ORGPW** when simulation begins. If inorganic fertilizer has been used as the sole source of P, then **ORGPW** in the plow layer can be left blank.

It should be recognized by the model user that several years may be required for the field soil to equilibrate with management. If fertilizer has been used, and animal waste application is considered as an alternate system without **ORGNW** and **ORGPW** when simulation begins, several years are required to equilibrate with the new loadings. The length of time required is climate dependent as well as waste-loading dependent.

A relationship was given in the model documentation section of this paper (Part I) for flow of labile phosphorus between plant available and active mineral P (PMINP). The relationship for rate, MPR, is a function of a soil water, SWF in cm, soil temperature, T_s in centigrade, labile P, **PLAB** in kg/ha, and PSP is the phosphorus sorption coefficient. The relation is repeated here for convenience as

$$MPR = 0.1\ (SWF)\ EXP(0.115\ T_s - 2.88) \left[PLAB - PMINP \left(\frac{PSP}{1 - PSP} \right) \right] \qquad \textbf{[30]}$$

Phosphorus sorption is a function of soil type (calcareous, slightly weathered, or highly weathered), and varies by soil horizon. By assuming equilibrium for initialization, MPR = 0, with SWF and T_s optimum (value of 1), the part of eqn. [9] in []'s can be solved for PMINP.

It was also stated in Part I of this paper that at equilibrium, stable mineral P (SOILP) is four times active mineral P (PMINP), and that slow adsorption (flow) between the two pools is expressed as (Jones et al., 1984)

$$ASPR = ù\ (4\ PMINP - SOILP) \qquad \textbf{[31]}$$

For calcareous soils, Jones et al. (1984) stated that ù is approximately 0.00076/day, and for noncalcareous soils it is related to the rapid adsorption of labile P as

$$ù = EXP(-1.77\ PSP - 7.05) \qquad \textbf{[32]}$$

Assuming equilibrium, ASPR = 0, and with PMINP determined above, SOILP is estimated as 4 x PMINP in eqn. [10].

If total phosphorus, **TP**, is input to the model, the total mineral phosphorus (PMINP plus SOILP) is determined in the model by difference and partitioned by eqns. [9]-[11] as described above. Total mineral P (MINP) is determined as

$$MINP = \lfloor (TP)\ (SOLMAS) \rfloor - SORGP - SORGPW - FOP \qquad \textbf{[33]}$$

Then

$$MINP = PMINP + SOILP = PMINP + (4)PMINP \qquad \textbf{[34]}$$

and

$$PMINP = \frac{MINP}{5} \qquad \textbf{[35]}$$

SOILP is determined as above.

Fresh organic P in crop residue, FOP, is estimated in the model as 10 kg/ha and distributed in the root zone. This is analogous to the initialization of fresh organic nitrogen, FON.

If site-specific **TP** data are not available for input, and PMINP and SOILP are estimated as above, the model then calculates percent **TP** from the relation

$$TP = \left(\frac{SORGP + SORGPW + FOP + PMINP + SOILP}{SOLMAS} \right) 100 \qquad \textbf{[36]}$$

It cannot be over emphasized that the model user should make every effort possible to obtain the best data possible for best simulation results. The model can give no better results than the input data.

UPDATABLE PARAMETERS

Parameters that change with management practices requiring periodic changes such as date and amount of fertilizer applied, date, amount, and composition of animal waste applied, and tillage dates and depths are user updated in the parameter file. These parameters are not constant throughout the simulation period, for example, a farmer incorporate a blended fertilizer a few cm deep at planting time, and topdress ammonium nitrate at some time just prior to the fruiting stage of the crop. The rate of application, fertilizer composition, and depth of incorporation are different on the two different dates. The user must have the capability to change these parameter values when necessary.

PDATE

The parameter **PDATE** denotes when an update period begins, i.e. the beginning date on which updatable parameters are valid. The period continues until the next **PDATE** is encountered. It consists of two parts: the year within the rotation cycle, and the Julian day of the year. Update periods cover the rotation cycle, and are reused in a long-term simulation. The model reads **PDATE** and, beginning with **NBYR** on card 4, calculates the absolute date with the calendar year, and writes a dummy file for the entire simulation period before the model begins the daily computations. Thus, a **PDATE** of 1050 in a 2-year rotation with **NBYR** = 1985 and **NEYR** = 1991 would be written into the dummy file as 1985050, again as 1987050, as 1989050, and as 1991050.

Fertilizer and Animal Waste Applications, and Tillage Operations

Two parameters, **NF** and **NTIL**, are needed to denote the number of fertilizer applications, either inorganic or animal waste, and the number of tillage operations that may affect surface crop residue and surface-applied animal waste. These are operations that occur within the update period. The number of fertilizer/animal waste applications include fertigation, i.e. application of fertilizer in irrigation, and irrigation application of liquid waste such as lagoon effluent. Although it is not generally recommended, the user can make liquid waste applications daily. This may be feasible in some soil/climatic regions.

Tillage operations include those that may incorporate surface residue and animal waste, and/or mix chemicals, residue, or animal waste in the plow depth. Combines, hay balers, silage choppers, vegetable harvesters, tobacco pickers, or other harvesting implements are not included as "tillage" operations. Although these implements affect residue distribution on the surface, they do not incorporate or mix residue with the soil. The amount and composition of residue are crop-dependent, and their dates of occurrence will be denoted by other parameters. One common management option is included that does not incorporate or mix, but removes the residue and residue-N and residue-P from the system is "burn". It is common in multi-crop systems in many areas and removes all of the residue. It really cannot represent burning of sugarcane where it is done before harvest. Sugarcane burn-harvest should be represented as harvest where all of the cane and burned leaves and thatch are removed in one operation.

Crop Harvest

Date of crop harvest, **DHRVST**, signals the model to portion out nutrients and residue into yield, and surface and root zone masses. Only one crop with its associated **DHRVST** is included in an update period, and a new **PDATE** generally either coincides with **DHRVST** or is 1 day after harvest. Therefore, a double- or multi-crop system has an update period for each crop. Multiple cuttings of alfalfa or bermuda grass hay would be represented with an update period for each cutting.

The date of harvest is shown as the year of the rotation cycle plus the Julian day of the year, for example, **DHRVST** for a winter small grain may be 1160. This would represent day 160 of year 1 of the rotation cycle.

One major exception exists for the annual crop or multi-crop harvests. A forest may or may not be harvested (clear cut) during a simulation period. A simulation may begin with a forest transplanting and logging may not occur during the simulation period. If a simulation period is 20 years, and clear cutting occurs some time after simulation ends, then **DHRVST** could be set as 21366 simply to signal the model that harvest does not occur during the simulation period. Another condition that might be represented is when simulation begins some years after transplanting and is not harvested during the simulation period. In a 20-yr simulation for this situation would result in **DHRVST** = 21366. Still another situation where harvest does not occur each year but does occur during the simulation would be a forest cutting during the last year of a 20-year simulation. Each year (update) the harvest date would be the same, say on day 250 of the 20^{th} year, or **DHRVST** = 20250.

Crop Characteristics--**LEG, PY, DMY, CNR, RNP, C1, C2, PERNNL**

Characteristics of 78 crops have been included in the **GLEAMS** model internal data base. The characteristics required for model operation include legume identification (**LEG**), potential yield **(PY**) in kg/ha, the ratio of total dry matter to yield (**DMY**), carbon-nitrogen ratio at harvest (**CNR**), ratio of nitrogen to phosphorus (**RNP**), and coefficient (**C1**) and exponent (**C2**) of nitrogen content of the crop. These data are shown by crop (**ICROP**) in Table N-2. The potential yield may vary considerably for different soil-climatic regions, and the user can input site-specific values if desired. Potential crop height may vary with climatic region and crop variety. The model user can change the value from that given in Table N-2. If crops other than those listed in Table N-2 are used in the model simulation, the user must supply all the characteristic data.

Potential yield represents the harvestable portion of the crop, e. g. corn grain, soybeans, alfalfa hay, potatoes, etc. For some crops, it may include both the normally harvested portion plus the above-ground forage, e.g. peanuts plus hay, corn silage, rye grain plus straw, and etc. This allows the appropriate dry matter to be taken out of the system at harvest time. Data in Table N-2 for alfalfa (**ICROP** = 2) are somewhat unique in that potential yield is given for each of 2, 3, or 4 cuttings of hay in a year. The **PY** decreases for each cutting. These data must be input by the user for each period, i. e. for each **PDATE**. Alfalfa harvested for seed (**ICROP** = 1) is generally the second cutting of a season in states north of Kansas and the third cutting in states on a latitude with and south of Kansas. If model users make an application of alfalfa for seed, these generalized considerations can be simulated.

The potential yield for green manure crops should be the total dry matter production including crop roots. For example, rye winter cover crop, vetch, alfalfa growth after seed harvest, meadow not cut for hay, or any other crop not harvested, all dry matter production and its nitrogen and phosphorus content is returned to the appropriate pools for mineralization. The potential yield data given in Table N-2 is the harvestable portion that removes biomass and its N and P content from the system. Winter rye grain plus straw potential yield is given in Table N-2 (**ICROP** = 52) as 5,240 kg/ha. If this value is accepted by the user, then it should be multiplied by 1.35 to get the potential total dry matter production (7,074 kg/ha) for green manure plow-down. The appropriate value of **DMY** (dry matter ratio) is discussed below. For crops not listed in Table N-2, for example, winter vetch, the total dry matter potential including roots should be entered.

Potential yield for forests varies with climate, species, and management practices such as fertilization, control of competing vegetation and underbrush, and thinning. Fast-growing species of pines for pulpwood production has a higher **PY** than lumber-producing species. Some management practices consist of thinning the fast-growing species for pulpwood/chipwood after several years of growth with the remaining production used for lumber in softer SPF grades. Also, potential yield varies considerably when considering saw timber (with clean-up of hardwood limbs for pulpwood/firewood) or chipping. The **PY** values in Table N-2 for **ICROP** = 69-71 are only suggested annual values for average conditions of mature forests, and should be replaced by the model user to represent climate and management being considered in a simulation. The increasing common practice of applying sewage effluent on forested areas is also a factor in setting **PY**. Obviously a potential yield is meaningless for developing forest, e.g. years 1-8, but it is a means-to-the-end for estimating forest biomass production and the uptake of nutrients.

Another important factor in Table N-2 concerns the dry matter ratio **(DMY**). Root weight is assumed in **GLEAMS** to be 25% of the total dry matter production. Those crops shown in the table as "grain + straw", for example, barley--grain + straw, **DMY** is generally given as 1.35. This will result in 25% of the total dry matter assigned to root weight at harvest and no surface residue. Root crops such as carrots, onions, potatoes, etc, have **DMY** less than 1.35. Those crops have some roots that contain nitrogen and phosphorus and become FON and FOP at harvest, but certainly less than 25% of the total dry matter. Also, there are some above ground portion of the total dry matter that is treated as surface residue at harvest. For those crops with **DMY** < 1.35, that dry matter greater than the yield portion of the crop is divided equally between root weight and surface residue weight.

Weeds, **ICROP** = 78 in Table N-2, has a value of **DMY** = 0.0. This is a special situation where there is not a harvestable portion removed. The yield, as adjusted from potential yield for water and nutrient stress, is divided equally between roots and surface residue. If the weeds are killed by tillage, a portion of the surface residue is incorporated (mixed) into the soil with the appropriate N and P content that becomes a part of FON and FOP.

Crops given in Table N-2 other than weeds may not be harvested with removal of yield and associated N and P, for example, rye winter cover plowed under for green manure. **ICROP** = 52 can be entered with an appropriate value for **PY** (discussed above) and all of the default values for **CNR**, **RNP**, **LEG**, **C1** and **C2** are valid except **DMY**. In this case, **DMY** = -1.0 should be entered. The negative sign indicates that biomass with its N and P content is not removed at harvest. The entire biomass will remain with 25% roots in the ground and 75% above ground residue that will change with tillage.

An additional feature for **DMY** was added to **GLEAMS** version 3.0. In 1997, Dr. A. B. Bottcher, Soil Water & Engineering Technology (SWET), Gainesville, Florida, requested a modification of **GLEAMS** to represent removal of all above-ground biomass, and root mass and nutrient pools in the top 1-cm of soil with sod harvest. Since sod farming is an important management system in many areas, this was a desirable improvement of **GLEAMS**, and it now a part of version 3.0. The modification was represented by setting **DMY** = 100.0 in the parameter file, and the model source code changed to accomplish the biomass removal. This is the only change necessary for the model user, and the removal is given in the output harvest information.

The dry-matter ratio for forest crops vary with species. The values of **DMY** for **ICROP** = 69-71 are only approximate, and the user is cautioned to supply the best estimate that may be obtained for the specific management system represented..

Perennial crops, such as alfalfa, sugarcane, forests, and most grasses, generate new roots throughout the entire root zone rather than beginning from the soil surface in each successive year of growth. Only in the initial year of planting does the root growth proceed from zero depth to the maximum **(RD** in **GLEAMS**). A code, **PERNNL**, is designated for each of the 78 crops listed in Table N-2. The code is 0 for non-perennial, or annual crop, and 1 for perennial crop. If a crop is designated a perennial, root growth does not begin at zero depth such as after each cutting of hay.

Values of carbon:nitrogen ratio (**CNR**) and ratios of nitrogen:phosphorus (**RNP**) are fairly well established for the harvestable portion of most agricultural crops. The **GLEAMS** model assumes that all portions of the crop have the same **CNR** and **RNP**, that is, the seed, roots, stems, and stover all have the same ratios. It is well known that this is not exactly true for all crops, but it simplifies the model development and user input. Therefore, estimates of these parameters in Table N-2 are “happy mediums” as opposed absolute values for individual plant parts. It has been shown in validation to give good results (Knisel, 1993) when comparing alternative management systems.

CNR and **RNP** values for trees vary with species, and the values in Table N-2 for **ICROP** = 69-71 are only approximate at best. These ratios are not commonly used in the forest industry, but are estimated here to enable the use of **GLEAMS** for forest applications plant nutrient considerations. Again, as with most of the parameters for forest applications, model users are urged to obtain the best estimates possible for these parameters.

Parameters **C1** and **C2** are coefficient and exponent, respectively, to calculate the optimum (demand) nitrogen content of the crop. From the nutrient model documentation, eqn [95] (Knisel, 1993), the percent nitrogen content of the dry matter, CN, is

$$CN = C1\ (GRT)^{C2} \qquad [37]$$

where GRT is the growth ratio expressed as ratio of actual to potential **LAI**. The user is referred to the model documentation for discussion of nitrogen uptake.

The coefficient and exponent parameters are included in the nutrient data base for the 78 crops listed. The values given are for "optimum" content, and do not represent a "flush" uptake for high fertility conditions such as with high animal waste loadings. **C1** is a scale factor and **C2** is a shape factor in the exponential relation. An example of data base and high fertilization level for corn-grain is shown in figure N-2 for a non-stressed condition. In this particular example, a 35% increase in nitrogen concentration is represented for the high fertilization rate. Estimation of the increase is somewhat subjective. As a guide, 200-225 kg N/ha (about 180-200 lb N/ac) is normally recommended for 9,400 kg corn/ha (150 bu/ac). This is slightly less than the 1.3% in the data base, but rainfall and mineralized nitrogen will supply an additional amount to account for the approximate 1.3%. The 35% increase in nitrogen content could be expected to relate to about 270-300 kg N/ha. perhaps supplied by high application rates of animal waste. Another way of considering high fertilization levels is by an increase in potential yield, **PY**, and leave the **C1** coefficient the same as that in the data base.

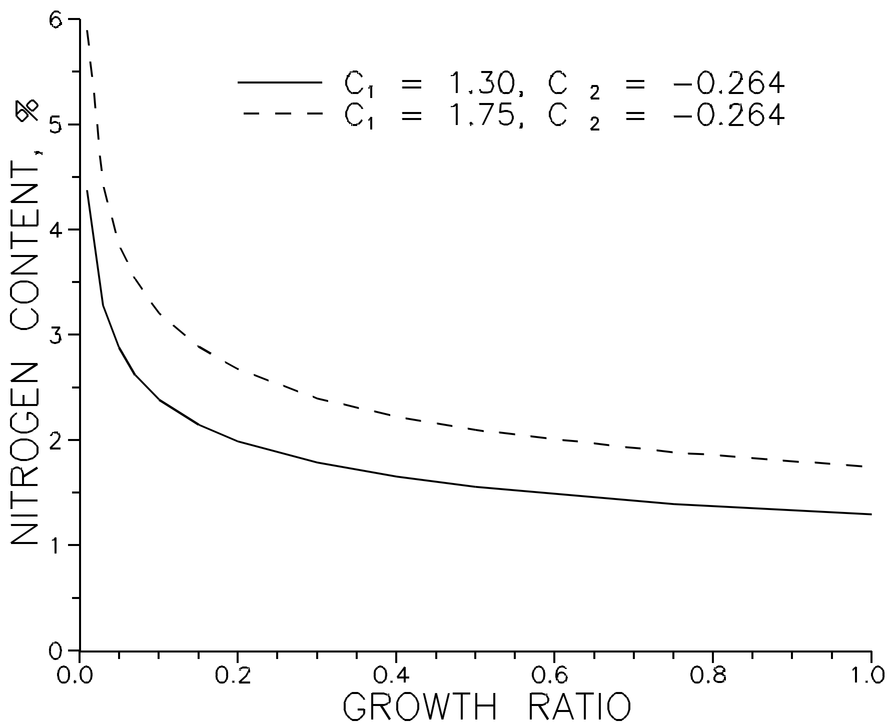

Figure N-2. Optimum nitrogen concentration as a function of growth ratio for corn: solid line from data base; dashed line for high fertilization level.

The model is structured such that if **ICROP** is specified as one of those in the data base, the tabular values are used unless the model user enters different values. For example, when **ICROP** < 79, every parameter on the card can be left blank and the model uses tabular values. However, if the user wants to increase potential yield, only the value for **PY** has to be entered on the card in the parameter file and all other values from Table N-2 are used. Likewise, a "flush" of nitrogen uptake can be represented by only increasing the parameter **C1**. The data in Table N-2 for horticultural crops and some field crops were taken from Lorenz and Maynard (1980).

Perhaps the least known plant nutrient parameter values for forest application are the coefficient and exponent, **C1**and **C2**, for eqn. [37] above. **C1**and **C2** undoubtedly change with stage of forest growth (year-to-year), but it is impossible to give guidance to these parameters and their changes at this time. The values given for **ICROP** = 69-71 in Table N-1 are the best estimates by the model developers, and should be updated by the model user when possible.

Fertilizer Application

Date of fertilizer application, **DF**, includes the year of the rotation cycle, and the Julian day of the year. **DF** can be any day beginning on **PDATE** until one day before the next **PDATE**. More than one fertilization can be made on one day to consider morning and afternoon application of dairy barn wash water, or animal waste plus additional inorganic phosphorus applications. These may not normally be performed, but the model can accept the data. Also, it is possible to apply lagoon effluent daily for 365 days a year if desired.

MFERT is a code to describe the fertilizer, inorganic or animal waste. This code indicates what parameters to enter on subsequent cards.

METHAP is a code to denote the method of application. There are five methods of application: surface, incorporated, injected, fertigation, and sprinkler application of liquid animal waste. Surface application does not result in mixing with the soil as does incorporation. Injection results in placement of the fertilizer or animal waste in a computational soil layer below the surface rather than mixing as with incorporation. Fertigation is the irrigation application of inorganic fertilizer with some specified amount of irrigation water. Irrigation application of liquid animal waste is the same as fertigation, i.e. applied with some specified depth of water that is an increase to soil water. However, some organic nitrogen and phosphorus and organic matter are added that must be input to the appropriate pools for mineralization.

If the **MFERT** code indicates the fertilization is an animal waste application, a code to indicate the animal type, **MTYPE**, is needed to obtain the proper characteristics from the data base. Animal waste composition varies with animal. A combination of seven animals and three waste types are included in the data base for user convenience. The 14 codes are listed below by **MTYPE**.

Solid	Slurry	Liquid
1 beef cattle	8 beef cattle	11 beef cattle
2 dairy cattle	9 dairy cattle	12 dairy cattle
3 horse	10 swine	13 poultry
4 municipal sludge		14 swine
5 poultry		
6 sheep		
7 swine		

If the user wants to specify the waste composition, then a code 15 is input for **MTYPE**.

Slurry is assumed to be applied as a solid or semi-solid. The mass (t/ha) of slurry or solid may be applied on the soil surface and incorporated by tillage on the day of application or on some later date. The waste composition, either data table or user supplied, operates on the mass to distribute the composition into the appropriate pools. Slurry may be injected (into a soil layer) and again the mass is manipulated to place the correct amount in the appropriate pools in the injection layer.

The **MTYPE** codes correspond to those in table N-3 which also gives the data base constituents. These will be described later.

Inorganic Fertilizer Specification

The specification of **MFERT** code for inorganic fertilizer application requires further information. If fertigation is also indicated by **METHAP**, the depth of irrigation water, **FRTWAT**, is required. Fertilizer must be moved into the root zone for plant uptake by mass flow. Therefore, sufficient water must be added to move the fertilizer into and below the surface 1 cm of soil. However, excess water is not wanted since it would only leach the fertilizer down where it could readily leach out of the root zone if a storm event occurred. Generally it is desired to only add enough water by fertigation to raise the soil water content in the Ap horizon to field capacity since most of the root activity is in that horizon. If recommendations are not available, the user must estimate **FRTWAT**, and the soil water content on application date DF is not known ahead of model simulation. An upper limit, PAWAP, cm, would be the volumetric plant available water times the thickness of the Ap horizon, DEPAP, cm, as

$$PAWAP = [(FC) - (WP)]\ (DEPAP) \qquad \textbf{[38]}$$

where **FC** is volumetric water content, cm/cm, of the first (Ap) horizon at 33 kPa, **WP** is volumetric water content, cm/cm, of the first horizon at 1,500 kPa, and DEPAP is the depth of the Ap horizon, cm. In humid regions where water deficit management is recommended, **FRTWAT** may be 50-75% of PAWAP.

Depth of incorporation, DEPIN, refers to the depth that granular fertilizer is incorporated into the soil, or the depth of injection such as with anhydrous ammonia application. If a surface application is made, such as a top-dress or fertigation, the depth of incorporation is 0. This differs from the pesticide component of the model because liquid pesticide application is assumed to mix with the top 1 cm of soil, and granules are generally incorporated. Surface applications of fertilizer result in additions to the SOLNH, SOLN, and SOLP pools on the surface of the soil to be moved into the top 1 cm with rain or tillage.

Fertilizer analysis and total mass applied determine the amounts of nitrate-nitrogen, ammonia-nitrogen, and labile phosphorus added. Contents of some common commercially-available blends are given in Table N-4. If user information indicates 300 lbs/ac of 16-20-0 fertilizer is applied, then **FN** = 53.76 (300 x 0.16 x 1.12 to convert lbs/ac to kg/ha), **FNH** = 0. and **FP** = 67.2 (300 x 0.20 x 1.12). For 400 lb ammonium nitrate/ac, **FN** = 400 x 0.165 x 1.12 = 73.92 kg/ha, **FNH** = 73.92, and **FP** = 0. The data in Table N-4 are percent of elemental N applied in the forms nitrate and ammonia, and elemental P in the form of P_2O_5. Some special fertilizer blends are made by some cooperatives and farmer-owned mixing operations. The application rate and depth of incorporation are sensitive parameters since they affect uptake and leaching.

Animal Waste Application and Composition

Animal waste application is represented as solid, slurry, or liquid. Rate of application (**RATE**) is expressed as kg/ha dry matter for solid and slurry, and equivalent depth of water for liquid. Method and handling and storage affects the moisture content at the time of application, i.e. open storage exposed to rain, pit storage, poultry litter with cane pumice, etc. Depending upon these and other factors, moisture content may range from 60 to 95% for solid, and 90 to 95% for slurry. The rate of dry matter application is a sensitive parameter, but if the same moisture content/dry matter application is used for alternative management practices, the relative differences in simulation response is insensitive to moisture content. Ranges of moisture content are given in some of the supporting tables at the end of this section.

DEPIN, the depth of animal waste injection in cm, is user specified. If animal waste is incorporated either the day of application or at a later date, then it should be coded as a surface application (**METHAP**) with **DEPIN** = 0.0 cm. Incorporation of animal waste is accomplished only by some tillage operation with the tillage depth specified (**DTIL**) as discussed below. This will automatically take care of the incorporation. **DEPIN** describes the depth to which animal waste slurry may be injected. All of the applied dry matter and its constituents are added internally by the model to the appropriate pools in the computational soil layer containing **DEPIN**. Specification of **DEPIN** for incorporation does nothing until a tillage operation is performed, and **DTIL** takes precedence.

Nitrogen and phosphorus components in the animal or municipal waste must be known for the model to distribute the correct amount in the correct pools. If the user specifies an **MTYPE** corresponding to those in Table N-3, all of the constituents are obtained from the default data base in the model. These data were compiled from a number of sources (American Society of Agricultural Engineers, 1975; American Society of Agricultural Engineers, 1985; Brogan, 1981; Dickey and Vanderholm, 1977; Loehr, 1977; Midwest Plan Service, 1979; Midwest Plan Service, 1983; North Carolina State University, 1982; Sommers, 1977; U.S. Soil Conservation Service, 1975). The constituents probably nearly approximate fresh manure without bedding or without having been stored. They represent a meaningful value that can be defined in a data base. If the user desires to use known site-specific values or estimates, additional information is given in some tables at the end of this section.

User-supplied data must include percentages of total nitrogen (**ATN**), organic nitrogen (APORGN), ammonia (**ANH**), total phosphorus (**APHOS**), organic phosphorus (**APORGP**), and organic matter content (**AOM**) as well as **WASTYP**, e.g. solid, slurry, or liquid. Nitrate content is calculated as the difference between **ATN** and the sum of **APORGN** and **ANH**. Labile phosphorus is calculated as the difference between **APHOS** and **APORGP**. If **ATN**, **ANH**, and nitrate are known, but not **APORGN**, then **APORGN** can be determined as the difference for input purposes. The same is true if **APHOS** and "available phosphorus" are known: **APORGP** can be determined as the difference for input purposes. The organic matter content may be taken as the volatile solids. The organic matter is used to calculate C:N and C:P ratios for use in the mineralization processes.

All of the animal waste constituents are sensitive parameters since they are directly related to ammonia, nitrate, and labile P in the total system. Therefore, the best possible estimate is needed, but it is even more important to be consistent from one management system to the next for comparative loadings.

Tillage

Tillage is significant in the nutrient component as it incorporates and mixes surface residue and its associated mineralizable nitrogen and phosphorus. Surface residue, or lack thereof, affects soil temperature and thus affects the mineralization and denitrification processes.

Date of tillage **(NTDAY**) is specified as year of the rotation cycle and Julian day. It can be specified on any day during an update period beginning 1 day after **PDATE**.

A total of 22 tillage implements (including "burn") are included in an internal data base. The codes **(LTIL**), description, and incorporation efficiency **(EFFINC**) and mixing efficiency (**FMIX**) are given in table N-5. More implements will be added as time permits. Any tillage operation that incorporates surface residue or mixes the residue in the tilled layer should be included in the parameter file. Specification of the **LTIL** codes in Table N-5 by the user eliminates the need to input **EFFINC** and **FMIX**. If other implements are included in the parameter file by the user, then their respective parameters must be given.

Depth of tillage (**DTIL**) must be input so the model can determine the computational layers affected by the operation. It is assumed that if **DTIL** extends even partially into a layer, the entire layer is considered tilled. This is necessary since any chemical, pool, or residue is assumed completely mixed in the layer for determining concentrations. Therefore, depth of effective tillage may be somewhat greater than specified **DTIL**. For example, if layer 2 is 5 cm thick and **DTIL** is 3 cm, the model will determine that layer 1 (1 cm) and layer 2 (5 cm) are tilled and mixing will be calculated the two layers.

PARAMETER EDITOR

An editor was written to aid the model user in developing nutrient parameter files or edit existing files. It was written in C-language and distributed only as executable code.

The editor establishes card and parameter sequences conditioned on codes and other parameter values. Pull-down menus, help tables, and data bases are included in the software for user assistance. Parameter description is given on a bar at the bottom of the screen, and ranges of parameter values are indicated as well. Some ranges may appear rather extreme, but this was intentional to not limit some extreme applications and systems. If estimated parameter values exceed the range given, the user can override the limit, but it cannot be done automatically without user action.

The description bar at the bottom of the screen also indicates when a help table or data base is available for a particular parameter. After accessing the table or data base, searching for particular values can be achieved by use of the arrow keys. Selection of a particular parameter or set of parameters can be re-turned to the parameter file by use of the return (enter) key, or use of the escape key returns to the file without returning data. Instructions for adding and deleting lines are included on the description bar. The parameter editor is very helpful in developing a file that will execute properly without some missing parameters.

A "Utility" menu has been added to the plant nutrient parameter editor for user convenience of converting English units to metric units. If a parameter is known in English units, for example residue weight **RESDW**, Alt + U in the editor will highlight the "conversion" bar for pull down with the <**ENTER**> key. The down arrow key can be used to select "From lb/ac to kg/ha". Type 1000 and press <**ENTER**>, and the value 1120 is returned to the parameter file. This addition keeps the user from having to convert with a hand calculator. All of the con-versions listed in Appendix Table A-2 are included in the parameter editor utility conversion.

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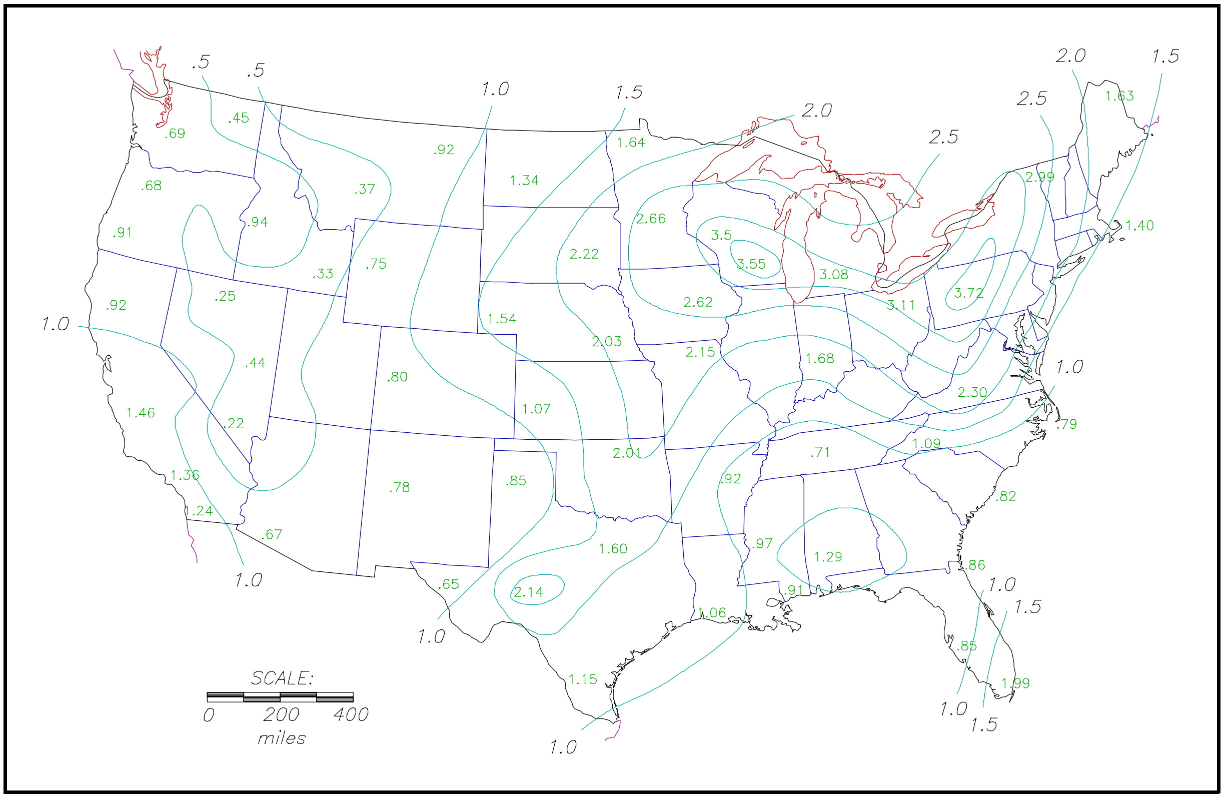

Figure N-1. Nitrogen (NO_3-N and NH_3-N), kg/ha/yr, contributions from rainfall throughout the USA [Adapted from Chapin and Uttormark, 1973].

Table N-1. Mineralizable nitrogen, total nitrogen, and organic carbon in surface soils of various soil orders (After Stanford and Smith, 1978).

Soil Order		POTMN	Total N	Organic Carbon	POTMN /TN	POTMN /OC
		kg/ha	kg/ha	kg/ha	%	%
Alfisol	mean[1]	391	2,156	23,333	18.1	1.74
	S.D.[2]	167	888	10,444	3.3	0.35
Aridisol	mean	289	1,689	13,111	15.3	2.00
	S.D.	207	800	7,111	6.2	0.77
Entisol	mean	342	1,844	17,556	18.2	2.06
	S.D.	176	800	10,222	6.2	0.83
Inceptisol[3]		245	2,267	26,222	10.8	0.94
Mollisol	mean	444	3,933	42,178	12.3	1.22
	S.D.	195	2,222	25,778	3.9	0.49
Spodosol	mean	600	5,822	75,556	10.6	0.89
	S.D.	109	1,867	42,667	1.5	0.35
Ultisol	mean	262	1,116	15,178	23.9	1.85
	S.D.	142	535	7,222	8.0	0.76
Vertisol[3]		389	2,600	28,600	15.0	1.36
All	mean	373	2,622	28,467	16.5	1.60
	S.D.	189	1,916	22,844	6.8	0.68

[1]Mean of several soils
[2]S.D. is standard deviation of the soils
[3]Only one soil was analyzed in the Inceptisol and Vertisol orders.

Table N-2. Crop characteristics in **GLEAMS** data base.

ID	Crop#	Poten. Yield PY	Dry Mat. Rat. DMY	C:N Rat. CNR	Rat. N:P RNP	C1	C2	Crop Ht.	Root Depth*		PER-NNL
		kg/ha						m	in	cm	
1	Alfalfa-seed	900	5.00	12	5.6	2.80	-0.165	1.0	RD	RD	1
2	Alfalfa-hay	4,500	1.00	12	5.6	2.80	-0.165	1.0	RD	RD	1
3	Winter Barley-grain	2,150	2.50	75	5.6	1.15	-0.296	1.0	RD	RD	0
4	Winter Barley-gr+straw	4,390	1.35	75	6.2	1.15	-0.296	1.0	RD	RD	0
5	Spring Barley-grain	1,880	2.50	75	5.6	1.15	-0.296	1.0	RD	RD	0
6	Spring Barley-gr+straw	4,200	1.35	75	6.2	1.15	-0.296	1.0	RD	RD	0
7	Beans-dry	1,950	2.50	24	3.3	1.00	-0.350	0.5	12	30	0
8	Beans-snap	6,720	2.00	12	10.6	1.26	-0.299	0.5	12	30	0
9	Beets	33,600	1.20	40	6.0	0.30	-0.562	0.4	12	30	0
10	Bermuda grass	17,920	1.35	80	6.7	1.25	-0.278	0.4	RD	RD	1
11	Bluegrass	4,480	1.35	80	7.4	1.50	-0.239	1.0	RD	RD	1
12	Broccoli	7,392	2.50	60	16.5	0.89	-0.352	0.6	12	30	0
13	Bromegrass	11,200	1.35	80	7.5	1.66	-0.217	1.2	RD	RD	0
14	Brussel sprouts	10,752	2.50	60	8.1	0.87	-0.357	1.0	12	30	0
15	Cabbage	44,800	1.50	40	9.3	0.38	-0.537	0.4	12	30	0
16	Cantaloupes	22,400	2.00	40	6.2	0.34	-0.535	0.3	18	45	0
17	Carrots	33,600	1.20	40	5.8	0.35	-0.529	0.3	12	30	0
18	Cauliflower	16,800	1.50	60	9.3	0.38	-0.537	0.6	12	30	0
19	Clover	4,480	1.35	24	5.0	3.00	-0.151	1.0	RD	RD	1
20	Corn-grain	9,400	2.50	80	5.9	1.30	-0.264	2.0	RD	RD	0
21	Corn-pop	3,760	2.50	80	5.9	1.30	-0.264	1.8	18	45	0
22	Corn-silage	44,800	1.35	75	5.9	0.40	-0.548	2.2	RD	RD	0
23	Corn-sweet	9,400	2.50	75	7.8	1.50	-0.213	1.8	18	45	0
24	Cotton	2,240	2.50	80	5.8	2.60	-0.119	1.5	RD	RD	0
25	Cowpeas-hay	4,480	1.35	24	4.3	3.00	-0.151	0.8	24	60	0
26	Cucumbers	13,440	2.00	40	6.0	0.34	-0.535	0.3	12	30	0
27	Eggplant	28,000	2.00	60	6.0	0.40	-0.548	0.8	18	45	0
28	Lettuce-Leaf	33,600	1.50	40	7.9	0.17	-0.657	0.3	12	30	0

Table N-2, continued. Crop characteristics in **GLEAMS** data base.

ID	Crop#	Poten. Yield PY	Dry Mat. Rat. DMY	C:N Rat. CNR	Rat. N:P RNP	C1	C2	Crop Ht.	Root Depth*		PER-NNL
		kg/ha						m	in	cm	
29	Lettuce-Head	44,800	1.50	40	7.9	0.17	-0.657	0.3	12	30	0
30	Lespedeza	4,480	1.35	24	5.0	2.05	-0.214	0.6	RD	RD	1
31	Millet, row-grain	3,000	5.00	80	5.0	1.30	-0.264	1.5	RD	RD	0
32	Millet, row-gr+forage	11,200	1.35	80	5.0	1.30	-0.264	1.5	RD	RD	0
33	Millet, bdcast-grain	3,000	5.00	80	5.0	1.30	-0.264	1.5	RD	RD	0
34	Millet, bdcast-gr+for	13,000	1.35	80	5.0	1.30	-0.264	1.5	RD	RD	0
35	Mustard greens	22,400	1.35	40	8.3	0.36	-0.494	0.4	12	30	0
36	Winter Oats-grain	3,200	3.00	75	3.5	1.30	-0.244	1.0	RD	RD	0
37	Winter Oats-gr+straw	7,680	1.35	75	3.5	1.30	-0.244	1.0	RD	RD	0
38	Spring Oats-grain	2,800	3.00	75	3.5	1.30	-0.244	1.0	RD	RD	0
39	Spring Oats-gr+straw	7,000	1.35	75	3.5	1.30	-0.244	1.0	RD	RD	0
40	Onions	44,800	1.20	60	5.8	0.29	-0.570	0.4	12	30	0
41	Orchardgrass	13,440	1.35	80	7.0	2.50	-0.128	1.2	RD	RD	1
42	Peas	6,720	2.25	24	7.7	1.12	-0.325	0.6	12	30	0
43	Pepper, bell	22,400	2.00	40	11.7	0.31	-0.555	0.8	12	30	0
44	Peanuts, 2-row	4,480	2.20	24	17.6	3.66	-0.107	0.4	18	45	0
45	Peanuts + hay, 2-row	8,960	1.10	24	17.6	3.66	-0.107	0.4	18	45	0
46	Peanuts, 4-row	5,040	2.20	24	17.6	3.66	-0.107	0.4	18	45	0
47	Peanuts + hay, 4-row	9,800	1.10	24	17.6	3.66	-0.107	0.4	18	45	0
48	Potatoes-Irish	39,200	1.25	60	8.2	0.43	-0.484	0.6	12	30	0
49	Rape seed	3,000	3.00	40	8.5	0.36	-0.494	0.8	RD	RD	0
50	Rice	4,540	2.50	75	4.8	1.37	-0.258	1.0	RD	RD	0
51	Winter Rye-grain	1,880	3.00	75	5.7	1.05	-0.290	1.0	RD	RD	0
52	Winter Rye-gr+straw	5,240	1.35	75	5.7	1.05	-0.290	1.0	RD	RD	0
53	Spring Rye-grain	1,700	3.00	75	5.7	1.05	-0.290	1.0	RD	RD	0
54	Spring Rye-gr+straw	5,000	1.35	75	5.7	1.05	-0.290	1.0	RD	RD	0
55	Safflower	1,120	3.00	80	4.5	1.20	-0.261	1.0	RD	RD	0
56	Sorghum-grain	5,000	3.00	80	5.1	1.67	-0.190	1.5	RD	RD	0

Table N-2, continued. Crop characteristics in **GLEAMS** data base.

ID	Crop#	Poten. Yield PY	Dry Mat. Rat. DMY	C:N Rat. CNR	Rat. N:P RNP	C1	C2	Crop Ht.	Root Depth*		PER-NNL
		kg/ha						m	in	cm	
57	Sorghum-forage	11,200	1.35	80	4.5	1.40	-0.228	2.0	RD	RD	0
58	Soybeans, row	3,020	2.25	24	5.3	2.30	-0.208	1.2	RD	RD	0
59	Soybeans, broadcast	3,200	2.25	24	5.3	2.30	-0.208	1.0	RD	RD	0
60	Spinach	22,400	1.35	40	8.3	0.36	-0.494	0.3	12	30	0
61	Squash	33,600	2.00	40	6.0	0.34	-0.535	0.5	12	30	0
62	Sugar beets	44,800	1.80	40	6.0	0.30	-0.562	0.4	24	60	0
63	Sugarcane	67,200	1.80	80	5.1	0.17	-0.686	2.5	RD	RD	1
64	Sunflower	2,240	3.00	80	4.5	1.20	-0.261	2.0	RD	RD	0
65	Sweet potatoes	22,400	1.30	60	7.0	0.42	-0.489	0.3	24	60	0
66	Timothy grass	5,600	1.35	80	6.0	1.20	-0.261	1.5	RD	RD	1
67	Tobacco	3,360	2.00	75	11.7	3.84	-0.034	1.5	RD	RD	0
68	Tomatoes	56,000	1.45	40	8.6	0.27	-0.556	1.0	24	60	0
69	Trees-conifer	17,500	2.00	100	4.5	1.00	-0.750	10.0	RD	RD	1
70	Trees-hardwood	17,500	2.00	80	4.5	1.00	-0.750	10.0	RD	RD	1
71	Trees-hardwood + conifer	17,500	2.00	90	4.5	1.00	-0.750	10.0	RD	RD	1
72	Turnips	36,300	1.10	40	8.3	0.36	-0.494	0.4	12	30	0
73	Watermelon	22,400	1.50	40	6.0	0.34	-0.535	0.3	24	60	0
74	Winter Wheat-grain	3,360	2.50	75	5.3	1.00	-0.301	1.0	RD	RD	0
75	Winter Wheat-gr+straw	6,720	1.35	75	5.3	1.00	-0.301	1.0	RD	RD	0
76	Spring Wheat-grain	3,000	2.50	75	5.3	1.00	-0.301	1.0	RD	RD	0
77	Spring Wheat-gr+straw	6,000	1.35	75	5.3	1.00	-0.301	1.0	RD	RD	0
78	Weeds	1,000	0.00	60	7.0	1.10	-0.264	1.0	RD	RD	0

Crop abbreviations: gr = grain; for = forage; bdcast = broadcast;
* Root depth for vegetables from Lorenz and Maynard, 1980; Smittle, D. August 24, 1992. Personal communication.

Table N-3. Animal waste composition for GLEAMS model data base (default values).

Code	Description	Total N	Orgn. N	NO_3-N	NH_4-N	Total P	Orgn. P	Sol. P	O.M.
		Percent							
1	Beef, solid @	4.8	3.23	.03	1.54	1.6	1.52	.08	85.0
2	Dairy, solid	4.4	3.32	.02	1.06	0.82	0.79	.03	86.0
3	Horse, solid	2.9	1.999	.001	0.90	0.50	0.498	.002	80.0
4	Municipal sludge	4.1	2.818	.002	1.28	1.72	1.719	.001	58.8
5	Poultry, solid	6.2	4.12	.03	2.05	2.90	2.85	.05	77.7
6	Sheep, solid	4.5	3.05	.01	1.44	0.79	0.785	.005	84.2
7	Swine, solid	7.5	4.29	.01	3.20	2.50	2.495	.005	80.0
8	Beef, slurry #	1.5	0.89	.04	0.57	0.16	0.14	.02	35.0
9	Dairy, slurry	2.7	1.62	.02	1.05	0.17	0.14	.03	40.0
10	Swine, slurry	1.0	0.34	.02	0.64	0.4	0.38	.02	39.0
11	Beef, liquid *	0.30	0.09	.01	0.20	0.10	0.01	.09	0.15
12	Dairy, liquid	0.29	0.09	.01	0.19	0.11	0.03	.06	0.13
13	Poultry, liquid	0.34	0.04	.01	0.29	0.09	0.01	.08	0.12
14	Swine, liquid	0.28	0.04	.01	0.23	0.10	0.02	.08	0.14
15	User defined								

@ Solid manure data expressed on dry weight basis; 15-25% solids.
# Slurry data expressed on wet basis; 4-15% solids.
* Liquid effluent expressed as liquid volume; < 4% solids.

Table N-4. Nitrate, Ammonia, and Phosphorus Content of Common Commercial Fertilizers (from Millar and Turk, 1949; Meister, 1987).

Fertilizer	Nitrogen as nitrate	Nitrogen as Ammonia	Phosphorus[1] as P_2O_5
	percent		
5-5-5	5	0	5
16-20-0	16	0	20
Sulfate of ammonia	0	21	0
Nitrate of soda	16	0	0
Calcium nitrate	15	0	0
Ammonium sulfate	0	21	0
Ammonium nitrate	16.5	16.5	0
Ammonium chloride	0	26	0
Anhydrous ammonia	0	82	0
Urea	0	42	0
Urea-ammonium nitrate solution	0	30-32	0
Ground phosphate rock	0	0	25-35
Superphosphate	0	0	16-20
Double or triple (treble) superphosphate	0	0	40-50
Calcium metaphosphate	0	0	63

[1]Expressed as phosphorus in the form of P_2O_5; percentages used directly

Table N-5. Tillage implement code, incorporation efficiency, and mixing efficiency of tillage implements included in **GLEAMS** data base.

ID No. (LTIL)	Implement	Incorporation Efficiency	Mixing Efficiency
1	Anhydrous ammonia applicator	0.05	0.05
2	Bedder--lister	0.95	0.05
3	Burn	0.00	0.00
4	Chisel	0.10	0.05
5	Cultivator--field (Hoeme)	0.10	0.10
6	Cultivator--row	0.10	0.10
7	Digger--peanut	0.05	0.05
8	Digger--potato	0.15	0.05
9	Disk harrow-offset	0.85	0.60
10	Disk harrow--tandem	0.75	0.50
11	Disk tiller	0.30	0.05
12	Disk plow	0.80	0.40
13	Disk plow--one way	0.50	0.50
14	Do-all	0.10	0.25
15	Drill--deep furrow (dempster)	0.30	0.05
16	Drill--small grain	0.05	0.05
17	Harrow--spike tooth	0.05	0.05
18	Harrow--spring tooth	0.05	0.05
19	Moldboard plow	1.00	0.25
20	Paraplow	0.05	0.05
21	Planter--in-row chisel	0.05	0.05
22	Planter--knife, disk, sweep	0.05	0.05

Table N-6. Daily Production and Composition of Fresh Manure (feces and urine) from USDA (1975)

Source	Manure Production[1]	Total Solids	Volatile Solids[2]	Total N	Total P
			kg/day/1000 kg live weight		
Dairy cattle					
Range	72-90	6.8-13.5	5.7-7.9	0.29-0.51	0-026-0.10
Average	85	9.3	6.9	.37	.069
Percent[3]		10.9	74	4.0	.74
Beef Cattle					
Range	41-88	6.0-11.1	4.8-8.2	.30-.58	.023-.17
Average	62	8.9	6.9	.43	.09
Percent		14.4	78	4.8	1.0
Swine					
Feeder					
Range	50-90	6.0-9.0	4.0-7.0	.20-.70	.09-.27
Average	69	7.2	5.7	.45	.17
Percent		10.4	79	6.2	2.4
Breeder					
Range	----[4]	----	----	----	----
Average	50	4.3	3.2	----	----
Percent		8.6	74	----	----
Poultry					
Range	32-67	9.0-17.4	8.0-12.9	.45-1.5	.20-.75
Average	53	13.9	10.8	.86	.40
Percent		26.2	78	6.2	2.9
Sheep					
Range	30-40	8.4-10.7	6.0-9.1	.34-.45	.04-.12
Average	36	9.5	8.0	.40	.075
Percent		26.4	84	4.2	.79
Horses					
Range	40-60	----	----	----	----
Average	50	17.5	----	.30	.12
Percent		35.0	----	1.7	.69
People					
Range	----	2.4-4.4	1.1-2.6	.14-.26	----
Average	31.2	3.4	2.0	.20	.024
Percent		10.9	59	5.9	.71

[1] Wet weight
[2] Volatile solids is equivalent to organic matter content
[3] Total solids as percent of manure production; remaining components are expressed as percent of total solids; all are based on averages
[4] Dashes indicate data are not available

Table N-7. Animal Waste Composition With Bedding or Litter, and Storage (from Loehr, 1974)

Source	Total N	Ammonia N	Total P	Mois-ture[1]
	------------------percent------------------			
Dairy cattle				
Fresh		4.4	3.4	0.9
Fresh bedding	2.9-3.9	.3-2.0	.8-1.0	
Stored with bedding	2.3	.3-.8	.2-.7	
Milk center[1]	.01-.42	.013	.0058	99.5
Beef cattle				
Fresh	1.8-8.5	----	.6-5.9	73-78
Straw litter, 6 mos. in open	1.8-4.3	----	.6-1.2	64-86
Chicken				
Deep woodshaving				
Hen				
Inhouse	1.0-3.5	----	.17-2.3	6-71
12-14 mos. build-up in house	1.7-2.6	----	.48-.92	31-32
Stored 2-3 mos. under cover	1.4-3.4	----	.31-2.7	13-81
Stored >12 mos. under cover	.4-2.7	----	.26-1.5	28-64
Stored <6 mos. in open	.9-1.8	----	.74-1.0	61-67
Stored >6 mos. in open	.9-3.1	----	.31-1.5	9-65
Broiler				
Inhouse, 8-12 wks in making	.7-3.4	----	.09-1.1	22-70
Inhouse, 8-22 wks in making	.8-2.8	----	.8-.9	18-66
10 wks in making, stored 3 wks in open	2.6-3.6	----	1.2-1.4	26-30
Stored 4-6 mos. under cover	2.0-3.3	----	1.0-1.2	24-36
Stored <12 mos. in open	0.6-3.7	----	.3-1.0	23-73
Stored 3-4 yrs. in open	1.3-2.2	----	1.0-1.4	31-50

[1] Wet weight basis

Table N-8. Animal waste composition of slurry (from Loehr, 1974)

Source		Total N	Total P	Moisture
		---------------Percent, wet basis-----------		
Poultry		0.1-3.8	0.04-0.4 .04-1.0	77-99 73-98
Cattle	Fresh	.2-1.9		
	2-3 days in tank	.1-2.7	.01-.17	86-99
Swine				
Hogs		.1-.2	.04-.09	96-99
Pigs		.2-1.0	.01-.4	83-99

Table N-9. Composition of manure lagoon influent diluted to 4 percent total solids, typical values in parentheses (from USDA, 1975)

Source	Volatile solids	Nitrogen N	Phosphorus as P
	----------------------Percent----------------------		
Dairy cattle	62-85(74)	3.1-5.5(4.0)	.18-1.1(.75)
Beef cattle	52-92(78)	3.2-6.5(4.8)	.25-1.9(1.0)
Swine	55-98(79)	2.8-9.8(6.2)	1.25-3.75(2.4)
Poultry	58-92(78)	3.2-10.8(7.2)	1.45-5.5(2.75)

Table N-10. Characteristics of Animal Waste and Municipal Waste Treatment sludge (USDA SCS; URRG; Loehr)

		Element			
	Type	Total Nitrogen	Ammonia Nitrogen	Total Phosphorus	Volatile Solids[1]
		-----------------Percent-----------------			
Beef cattle	1	2.1	0.36	0.8	82
Dairy cattle, runoff	2	.015	.008	.005	.001
Dairy cattle	3	2.0	.48	.6	18
Horse	4	1.1	.15	.3	21
Poultry	5	5.0	3.0	1.8	75
Sheep	6	4.0	1.0	.6	28
Swine, runoff	7	.024	.013	.005	.01
Swine	8	2.8	.59	.6	45
Municipal sludge	9	5.2	2.1	2.5	80

[1]Volatile solids is equivalent to organic matter content

Table N-11. Manure Composition (from Quarles, et al., 1974)

	Moisture[1]	Volatile solids	Total N	Ammonia N	Total P
	----------------------Percent-------------------------				
Beef cattle (360 kg average weight)					
Fresh manure/slotted floor/shallow pit	85	79	3.6	1.2	0.9
Biodegraded manure	29	69	3.1	1.1	1.5
Dirt/moderate slope/runoff 18.6 m^2/head	99	50	1.9	.7	.7
Dirt/steep slope/runoff (18.6 m^2/head)	99	50	1.9	.7	1.1
Paved lot/runoff (4.6 m^2/head)	99	52	7.0	1.3	.7
Slotted floor/deep pit	85	53	3.7	1.3	1.0
Housed/solid floor/manure + bedding	50	47	2.2	.8	.8
Dairy cattle (590 kg average weight)					
Stall barn/milk room waste	99	--	1.3	.07	1.1
Stall barn/manure + bedding (46% confined)	81	85	2.7	1.7	.5
Free stall barn/milk center waste	99	--	8.8	2.6	1.2
Free stall barn/manure + bedding (90% confined)	81	85	2.7	1.7	.5
Free stall/liquid storage/slotted floor (100% confined)	88	--	4.4	1.2	
---	Free stall/barn/liquid flush (100% confined)				
98	--	4.4	1.2	---	
Cow yard/milk center waste	99	--	17.0	5.0	1.7
Cow yard/yard manure	28	69	3.1	---	1.5
Cow yard/runoff (18.6 m^2/head)	99	47	1.9	---	.7
Swine (45 kg average weight)					
Solid floor waterwashed waste	99.9	100	10.0	5.5	3.2
Slotted floor/pit manure	97	100	10.0	5.5	3.2
Oxidation ditch mixed liquor	96	44	5.6	1.1	7.1
Lagoon effluent/unaerated	98	44	13.2	10.0	4.4
Manure	99.9	67	7.3	4.3	4.3
Dirt lot runoff	99.9	76	7.6	3.3	1.9

[1]Moisture on wet weight basis; other constituents on dry solids basis

G L E A M S

V E R S I O N 3.0

Appendix Tables

Table A-1. Julian calendar for non-leap year; for leap year add 1 day after February 28

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029		088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

Table A-2. Common conversion factors.

To Convert	Multiply By	To Obtain
ac	0.4047	ha
cm	0.3937	in
cm/ha	100000.	L/ha
ft	0.3048	m
ft^3	0.00283	m^3
gal	3.785	L
gal	0.1337	ft^3
ha	2.471	ac
in	2.54	cm
kg	2.2046	lb
kg/ha	0.893	lbs/ac
L	0.2642	gal
L	0.001	m^3
lbs	0.4536	kg
lbs/1000 gal	120.	µg/g (ppm)
lbs/1000 gal	120.	mg/L
lbs/ac	1.12	kg/ha
m	3.281	ft
m^3	35.31	ft^3
percent (concentration)	10000.	µg/g (ppm)
T/ac	2.24	t/ha
t/ha	0.4464	T/ac
MJ/m^2	23.87	Langleys