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DEMOGD:
DEMOGRAPHY WITH DISCRETE AGE COHORTS

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COMPUTER LIBRARY FOR AGRICULTURAL SYSTEMS SIMULATION

CLASS Document No. 7

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CLASS Document

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DEMOGD Documentation

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The project objective is to develop an approach to institutionalizing an analytical capacity for planning, policy formulation, program development, and project implementation for agricultural sector development within the public decision making structure of developing countries. A major component of the analytical capacity is a series of system simulation models tailored to the needs of the individual country. Much of the experience gained from the field activity and the knowledge gained from the theoretical and methodological research added to the present stock of knowledge about building and maintaining analytical capacities for agricultural sector development can be preserved and extended in the training provided through the Development Analysis Study Program and in the stock of model, component, and utility routine computer software documented in the Computer Library for Agricultural Systems Simulation.

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July, 1976

George E. Rossmiller
Director
Agricultural Sector Analysis and
Simulation Projects

CLASS Document

1. *Symbolic Name*	2. *Name*	3. *Type*	4. *Version No. and Date*
DEMOGD	Demography with Discrete Age Cohorts	component	1A 5/1/75

DEMOGD Abstract

DEMOGD models the demographic cohort-survival processes of birth, death, migration and aging for a population disaggregated by age and sex. Each cohort is of fixed length so that all individuals in the population take the same time to pass through it; all cohorts need not be of the same length, however. DEMOGD may be used, for example, for populations of humans, capital equipment and students--where "age" cohorts may be defined by chronological age, vintage, and class year, respectively.

The rate at which individuals pass through each cohort is adjusted for storage losses due to deaths and migrations. Furthermore, the user has the option of specifying whether births are to be generated endogenously (e.g., by natural reproduction) or treated as an input (e.g., investments in the case of capital equipment populations).

Inputs to DEMOGD are age-sex specific proportional fertility, death and net out-migration rates. DEMOGD computes population levels (total and by age and sex), births, deaths, migrations, the sex ratio, crude birth and death rates and the population's natural and net growth rates.

DEMOGD requires 379 decimal words of core storage and 4.6 milliseconds to execute (with six cohorts for each of two sexes) on a CDC 6500 computer.

I. Process Description

One of the components most commonly found in large-scale socioeconomic systems models is a population dynamics model. Population models, at one extreme, are often simple models in which a constant exponential growth rate is applied to an initial population level. At another extreme are found complex demographic systems in which the population is disaggregated by age, sex, income class, education level, geographic area, employment, etc.; fertility and death rates for each category are determined endogenously by socioeconomic conditions in the larger model; and migrations among categories are also linked to factors in the larger system.

DEMOGD takes a middle course in order to increase its general usefulness. Aggregated exponential growth models, for anything but very macro analyses, limit too greatly considerations of socioeconomic feedback effects on population growth and of population distribution effects on demographic outputs to the larger system. Demographic models which, on the other hand, disaggregate the population along several dimensions and compute fertility, death and migration rates endogenously have limited applications--limited to situations where the designated dimensions are applicable and where the chosen factors and functional forms determining fertility, death and migration rates are appropriate. In addition, where the population model is but one component of a much larger model, the use of computer resources (i.e., execution time and core requirements) becomes a real constraint to the use of the more disaggregated models. DEMOGD is general enough, however, to be used, if desired in a particular application, as a subcomponent of a larger population component which computes the feedback effects to and from a still larger socioeconomic model and thus

passes endogenous fertility, death and migration rates to DEMOGD as inputs. In addition, such a larger population component can use DEMOGD repetitively to treat a multidimensional disaggregation of a single population as a collection of populations with possible migrations among them.

DEMOGD itself disaggregates a population by age and sex; and cohort-specific fertility, death and migration rates are treated as possibly time-varying inputs. The user has the flexibility to collapse either the sex dimension or the age dimension or both, if greater aggregation is desired. For example, for capital equipment populations, the sex dimension may not be appropriate. Even for cases where disaggregation by sex is inappropriate, the "sex" dimension may be redefined and used for another classification; e.g., cattle raised under modern and traditional management conditions. Further, the user has the option of specifying that births are not to be generated within the population by natural reproduction but rather by external factors or decisions. Again, capital equipment populations serve as an example, where "births" are investment decisions.

Finally, DEMOGD models age cohorts of discrete lengths. That is, the time spent in a given cohort is the same for every individual in the population; different cohorts need not be of the same length, however. The latter property is very useful for aggregating certain age groups of the population while examining others in more detail. If distributed rather than discrete, age cohorts are desired; i.e., if cohort staying times may be considered to vary among individuals in the population rather than be constant for every individual, CLASS component DEMOGC may be used in place of DEMOGD.

II. Technical Description

A. Mathematical model

DEMOGD is modeled in two parts. The first part simulates the cohort-survival process, and it computes the population for each age-sex cohort, for each sex, and the total.

At each time t, the simulation model computes the population level in cohort j of sex k using Euler integration to solve the differential equation:

$$(1) \quad \frac{dPOP_{jk}(t)}{dt} = -PLR_{jk}(t) \cdot POP_{jk}(t) + AR_{(j-1)k}(t) - AR_{jk}(t)$$

where:

POP -- population level in the cohort (people)

AR -- rate at which population matures out of a cohort (people/year)

PLR -- proportional loss rate due to deaths and migrations (proportion/year) (equation (6))

j -- indexes cohorts, j=1, ..., NC

k -- indexes sexes, k=1, ..., NSEX

NC -- the number of age cohorts

NSEX -- the number of sexes (NSEX = 1 or 2).

For j=1, the first age cohort, $AR_{0k} = BTH_k$, births of that sex per year.

Every $CLEN_{jk}$ years in the simulation, the maturation (or aging) rate of cohort jk is computed by:

$$(2) \quad AR_{jk}(t) = POP_{jk}(t)/CLEN_{jk}, \qquad t=0,\ CLEN_{jk},\ 2CLEN_{jk},\ \ldots$$

where:

CLEN -- the length of the cohort (years).

Equation (2) is an obvious, yet not uncommon, approximation in that it

assumes the population within a cohort is uniformly distributed through the cohort. Thus, the shorter the cohort is, the better the approximation will be. At other times during the simulation, AR is adjusted only for deaths and migrations occurring during the CLEN years:

$$(3) \quad \frac{dAR_{jk}(t)}{dt} = -PLR_{jk}(t) \cdot AR_{jk}(t), \qquad t \neq 0,\ CLEN_{jk},\ 2CLEN_{jk},\ \ldots$$

Thus, by computing aging rates and integrating to get population levels, (a) cohorts need not be of equal length, (b) population level changes are determined continuously rather than only at fixed intervals corresponding to the common cohort length, and (c) time-varying fertility, death and migration rates may be considered continuously rather than only at the fixed intervals (an important consideration if cohort lengths are long relative to response times to family planning and health programs and to changing economic conditions).

Finally, population by sex and total population are computed:

$$(4) \quad POPS_k(t) = \sum_{j=1}^{NC} POP_{jk}(t)$$

$$(5) \quad TPOP(t) = \sum_{k=1}^{NSEX} POPS_k(t)$$

where:

POPS -- population by sex (people)

TPOP -- total population (people).

The second part of DEMOGD computes births, deaths and migrations from fertility, death and migration rates (inputs to DEMOGD). It also computes growth rate statistics.

The total proportional rate at which people leave cohort jk for reasons other than aging, i.e., due to deaths and migrations, is PLR.

$$(6)\quad PLR_{jk}(t) = PMR_{jk}(t) + DR_{jk}(t)$$

where:

PMR -- proportional migration rate--input to DEMOGD (proportion/year)

DR -- proportional death rate--input to DEMOGD (proportion/year).

Deaths, then, are computed for each cohort and summed across cohorts, and total migration is calculated.

$$(7)\quad DTH_{jk}(t) = \begin{cases} DR_{jk}(t)\cdot POP_{jk}(t), & j=1, \ldots, NC-1 \\ DR_{NCk}(t)\cdot POP_{NCk}(t) + AR_{NCk}(t) & \end{cases}$$

$$(8)\quad TDTH(t) = \sum_{k=1}^{NSEX} \sum_{j=1}^{NC} DTH_{jk}(t)$$

$$(9)\quad TMR(t) = \sum_{k=1}^{NSEX} \sum_{j=1}^{NC} PMR_{jk}(t)\cdot POP_{jk}(t)$$

where:

DTH -- deaths from a cohort (people/year)

TDTH -- total deaths (people/year)

TMR -- total migration (people/year).

Notice that people aging out of the last, oldest cohort of the population are accounted as deaths (equation (7)).

Equations (10) and (11) compute total births and births by sex.

$$(10)\quad TBTH(t) = \sum_{j=1}^{NC} FR_j(t)\cdot POP_{j1}(t)$$

(11) $BTH_1(t) = PBF \cdot TBTH(t)$

$BTH_2(t) = TBTH(t) - BTH_1(t)$

where:

TBTH -- total births (people/year)

BTH -- births by sex (people/year)

FR -- fertility rate (proportion/year)

PBF -- proportion of births which are female.

If DEMOGD is used to model a population which does not reproduce itself naturally (or for which it is not desired to model reproduction), and births are determined exogenously to DEMOGD, e.g., capital investment, then equation (10) is not executed and TBTH is considered an input to DEMOGD. It is also possible to use DEMOGD for populations not disaggregated by sex.

Finally, DEMOGD generates a number of population statistics.

(12) $SR(t) = POPS_2(t)/POPS_1(t)$

(13) $CBR(t) = TBTH(t)/TPOP(t)$

(14) $CDR(t) = TDTH(t)/TPOP(t)$

(15) $PGRN(t) = 100(CBR(t) - CDR(t))$

(16) $PGRT(t) = PGRN(t) - 100 \cdot TMR(t)/TPOP(t)$

where:

SR -- sex ratio (not computed if the population is not disaggregated by sex)

CBR -- crude birth rate (proportion/year)

CDR -- crude death rate (proportion/year)

PGRN -- natural growth rate (percent/year)

PGRT -- net growth rate (percent/year).

Initial conditions must be specified for the inputs FR_j, DR_{jk}, and PMR_{jk} and for the cohort populations POP_{jk}. Outputs and internal variables (e.g., AR_{jk} and PLR_{jk}) are initialized by DEMOGD. Parameters which must be given values are PBF, $CLEN_{jk}$, NC, NSEX and the simulation step size DT.

B. Sample run

The sample computer run is a model of a human population disaggregated into six male and six female cohorts. The model assumes constant proportional annual fertility, death and migration rates. The six female cohorts are of length 5, 7, 6, 20, 12 and 30 years, respectively, so that the third, fourth and fifth cohorts represent the reproductive age with fertility rates of .1, .25 and .05, respectively. The six male cohorts, defined relative to labor force participation, are of length 5, 10, 15, 20, 15 and 15 years, respectively. Death rates, migration rates and initial cohort population levels are indicated in the list of the sample run executive program. The output of a ten-year simulation appears in Figure 1.

The results of sensitivity tests changing parameters by +10% and DT by -50% (the latter to test integration accuracy) are tabulated in Table 1.

Figure 1

Sample Run Output

TIME	TOT. POP.	FEM. POP.	MALE POP.	DEATHS	BIRTHS
0.00	181000.	93000.	88000.	4988.	8350.

SEX RATIO	CRUDE BR	CRUDE DR	NAT. GRTH.	NET GRTH.	MIGRN.
.95	.046	.028	1.86	.47	2510.

FEMALE POPULATION COHORTS

22000.	14000.	11000.	27000.	10000.	9000.

MALE POPULATION COHORTS

22000.	20000.	21000.	17000.	6000.	2000.

TIME	TOT. POP.	FEM. POP.	MALE POP.	DEATHS	BIRTHS
2.00	182752.	93235.	89516.	4713.	8127.

SEX RATIO	CRUDE BR	CRUDE DR	NAT. GRTH.	NET GRTH.	MIGRN.
.96	.044	.026	1.87	.49	2519.

FEMALE POPULATION COHORTS

19733.	17946.	10808.	26106.	10385.	8257.

MALE POPULATION COHORTS

19733.	23706.	20836.	16822.	6323.	2096.

TIME	TOT. POP.	FEM. POP.	MALE POP.	DEATHS	BIRTHS
4.00	184534.	93618.	90915.	4513.	7919.

SEX RATIO	CRUDE BR	CRUDE DR	NAT. GRTH.	NET GRTH.	MIGRN.
.97	.043	.024	1.85	.48	2529.

FEMALE POPULATION COHORTS

18247.	21096.	10668.	25276.	10666.	7666.

MALE POPULATION COHORTS

18247.	26624.	20717.	16602.	6569.	2156.

TIME	TOT. POP.	FEM. POP.	MALE POP.	DEATHS	BIRTHS
6.00	186243.	94071.	93173.	4364.	7725.

SEX RATIO	CRUDE BR	CRUDE DR	NAT. GRTH.	NET GRTH.	MIGRN.
.98	.041	.023	1.80	.44	2538.

FEMALE POPULATION COHORTS

17283.	23674.	10573.	24500.	10856.	7183.

MALE POPULATION COHORTS

17283.	28980.	20633.	16346.	6747.	2183.

Figure 1 (cont'd)

TIME	TOT. POP.	FEM. POP.	MALE POP.	DEATHS	BIRTHS
8.00	187927.	94590.	93337.	4267.	7770.

SEX RATIO	CRUDE BR	CRUDE DR	NAT. GRTH.	NET GRTH.	MIGRN.
.99	.041	.023	1.86	.50	2556.

FEMALE POPULATION COHORTS

16817.	24001.	11901.	34124.	10967.	6779.

MALE POPULATION COHORTS

16817.	30838.	20576.	16058.	6866.	2182.

TIME	TOT. POP.	FEM. POP.	MALE POP.	DEATHS	BIRTHS
10.00	190007.	95349.	94658.	4239.	7970.

SEX RATIO	CRUDE BR	CRUDE DR	NAT. GRTH.	NET GRTH.	MIGRN.
.99	.042	.022	1.96	.60	2587.

FEMALE POPULATION COHORTS

17141.	22198.	14821.	22750.	11009.	6430.

MALE POPULATION COHORTS

17141.	32143.	20541.	15744.	6932.	2157.

Table 1

DEMOGD Sensitivity Test Results at Year 10

Run Definition	Change From Standard Value (a)	Female Population	Male Population	Sex Ratio	Natural Growth Rate	Migration
		1000 people	1000 people	--		1000 people/yr.
1. Standard run	0%	95.27	94.59	.9929	1.968	2.588
		% deviation from standard run				
2. Female initial cohort populations	+10%	+10.0	+3.55	-5.86	+5.89	+6.26
3. Male initial cohort populations	+10%	0	+6.46	+6.46	-6.10	+3.71
4. Female cohort death rates	+10%	-2.04	-.254	+1.82	-5.13	-.966
5. Male cohort death rates	+10%	0	-1.66	-1.66	-3.10	-.773
6. Female cohort migration rates	+10%	-1.46	-.328	+1.12	-1.68	+3.98
7. Male cohort migration rates	+10%	0	-1.15	-1.15	+1.07	+4.29
8. Fertility rates for females 12-17	+10%	+.514	+5.18	+.0101	+2.95	+.386
9. Fertility rates for females 18-37	+10%	+2.79	+2.82	+.03	+10.0	+2.12
10. Fertility rates for females 38-49	+10%	+.241	+.243	0	+.965	+.154
11. Proportion of births female	+10%	+3.54	-3.52	-6.83	+.813	+.0386
12. Simulation time increment DT	-50%	+.0525	+.0317	-.0202	-.254	-.0386

(a) Standard run values are given in the data of Figure 1.

III. Program Information

A. Program description

DEMOGD was programmed and tested in the following operating environment:

Machine: CDC 6500
Operating system: MSU Hustler 2 L239 LSD 32--an extension of CDC Scope 3.2
Compiler: CDC FTN V3.0-P357
Core requirements: 379 decimal words
CP compile time: 2.3 seconds
CP execution time (for sample run): 4.6 milliseconds
Tapes: none
Direct access files: none
FORTRAN library subprograms used: AMOD

DEMOGD is structured as one subroutine which models the cohort survival process of a population disaggregated by age and sex, given fertility, death and migration rates. Age cohorts are of discrete lengths but need not all be of the same length.

DEMOGD is divided in two parts which may be executed separately by specifying ICALL = 1 or ICALL = 2 in the argument list. This is significant only if fertility rates (FR), death rates (DR), or migration rates (PMR), depend on current population levels, which are computed in the first part of DEMOGD. If this is the case, two calls to DEMOGD (the first with ICALL = 1, the second with ICALL = 2) should be used, with FR, DR, and PMR calculated between the two calls. If this is not the case, i.e., if FR, DR and PMR are constant or depend only on past values of variables, a single call to DEMOGD (with ICALL = 0) will suffice. (Although in the sample program one call with ICALL = 0 rather than two calls would work because FR, DR and PMR are constant, two calls are used for illustrative purposes as if FR, DR and PMR depended on current population levels.)

B. Program implementation

All inputs and outputs are transmitted through the argument list, and no logical units are used by DEMOGD. See the list of the sample run executive program for an example of the call statement.

The program will <u>not</u> execute properly if NSEX has a value other than 1 or 2, or NOBTH has a value other than 0 or 1. If NSEX = 1, PBF need not be defined. If NOBTH = 1, TBTH must be defined outside of DEMOGD, and FR need not be defined. Finally, the following conditions must hold:

$DT > 0$

$NC \geq 1$ and integer

$CLEN_{jk} > 0$, $j=1, \ldots, NC$; $k=1, \ldots, NSEX$.

C. Program list

The computer programs for the sample run and for DEMOGD are listed below:

```
      PROGRAM DEMTST(OUTPUT)
      DIMENSION AR(6,2), BR(6), BTH(2), COHLEN(6,2), DR(6,2)
      DIMENSION DTH(6,2), PLR(6,2), PMR(6,2), POP(6,2), POPS(2)
      DATA POP / 22000., 14000., 11000., 27000., 10000., 9000.,
     +           22000., 20000., 21000., 17000., 6000., 2000. /
      DATA COHLEN / 5., 7., 6., 20., 18., 30.,
     +              5., 10., 15., 20., 15., 15. /
      DATA DR / .04, .007, .010, .015, .015, .1,
     +          .04, .008, .013, .017, .035, .1 /
      DATA PMR / .01, .01, .015, .02, .015, .005,
     +           .01, .01, .02, .02, .01, .005 /
      DATA BR / 0., 0., .1, .25, .05, 0. /
      DATA NC,NSEX / 6, 2 /
      DATA NOBTH,PBF / 0, .5 /
      DATA DT / .25 /
      T = -DT
      DO 40 I=1,999
        T = T + DT
        CALL DEMOGD(POP, POPS, TPOP, SR, COHLEN, AR, DR, CDR, DTH,
     +              TDTH, NOBTH, PBF, BR, CBR, BTH, TBTH, PLR, PMR,
     +              TMR, PGRN, PGRT, NC, NSEX, DT, T, 1)
        CALL DEMOGD(POP, POPS, TPOP, SR, COHLEN, AR, DR, CDR, DTH,
     +              TDTH, NOBTH, PBF, BR, CBR, BTH, TBTH, PLR, PMR,
     +              TMR, PGRN, PGRT, NC, NSEX, DT, T, 2)
        IF(MOD(I-1,8) .NE. 0.) GO TO 40
        PRINT90,T,TPOP,POPS,TDTH,TBTH
        PRINT91,SR,CBR,CDR,PGRN,PGRT,TMR
        PRINT92,POP
        IF(T .GE. 10.) STOP
 CONTINUE
 STOP
 FORMAT(5H1TIME,5X,9HTOT. POP.,2X,9HFEM. POP.,2X,9HMALE POP.,4X,
     +       6HDEATHS,5X,6HBIRTHS/1H ,F6.2,5F11.0)
 FORMAT(10H0SEX RATIO,2X,8HCRUDE BR,3X,8HCRUDE DR,3X,10HNAT. GRTH.
     +       1X,9HNET GRTH.,2X,6HMIGRN./1H ,F6.2,2F11.3,2F11.2,F11.0)
 FORMAT(30H0     FEMALE POPULATION COHORTS/1H ,6F11.0/
     +       28H0     MALE POPULATION COHORTS/1H ,6F11.0)
 END
```

```
SUBROUTINE DEMOGD(POP, POPI, TPOP, IR, COHLEN, AR, DR, CDR,
+                 DTH, TDTH, MOBTH, PBF, BR, CBR, BTH, TBTH,
+                 PLR, PMR, TMR, PGRM, PGRT, MC, MSEX, DT, T,
+                 ICALL)
```

TITLE - DEMOGRAPHY WITH DISCRETE AGE COHORTS

VERSION - 1A

DATE - 1 MAY 1973

PURPOSE - DEMOGD MODELS THE COHORT-SURVIVAL DEMOGRAPHIC PROCESSES OF BIRTH, DEATH, MIGRATION AND AGING FOR A POPULATION DISAGGREGATED BY AGE AND SEX, WHERE AGE COHORTS ARE MODELED BY DISCRETE DELAYS

INPUT REQUIREMENTS

VALUES TRANSMITTED THROUGH THE ARGUMENT LIST -- ALL INPUT VARIABLES

VARIABLES REQUIRING VALUES WHICH WILL NOT CHANGE DURING A RUN -- COHLEN(I,J), DT, MC, MOBTH, MSEX

VARIABLES REQUIRING VALUES WHICH MAY CHANGE DURING A RUN -- BR(I), DR(I,J), ICALL, PBF, PMR(I,J), T

VARIABLES COMPUTED BY THIS ROUTINE REQUIRING INITIAL VALUES -- POP(I,J)

OUTPUT VARIABLES

VALUES TRANSMITTED THROUGH THE ARGUMENT LIST -- AR(I,J), BTH(J), CBR, CDR, DTH(I,J), PGRM, PGRT, PLR(I,J), POPI(J), IR, TBTH, TDTH, TMR, TPOP

VARIABLE DEFINITION

AR(I,J) - AGING RATE IN INDIVIDUALS/UNIT TIME. (AGE,SEX)

ARP - RATE AT WHICH INDIVIDUALS ENTER THE NEXT COHORT IN INDIVIDUALS/UNIT TIME.

ART - AN INTERMEDIATE VALUE OF ARP IN INDIVIDUALS/UNIT TIME.

BR(I) - FERTILITY RATE IN PROPORTION/UNIT TIME. (AGE)

BTH(J) - BIRTHS IN INDIVIDUALS/UNIT TIME. (SEX)

CBR - CRUDE BIRTH RATE IN PROPORTION/UNIT TIME.

CDR - CRUDE DEATH RATE IN PROPORTION/UNIT TIME.

COHLEN(I,J) - COHORT LENGTH IN TIME UNITS. (AGE,SEX)

COHTIM - THE AGING RATE IS RECALCULATED EVERY COHLEN TIME UNITS. IF COHTIM IS LESS THAN DT, IT INDICATES IT IS TIME TO RECALCULATE THE AGING RATE. IF NOT, COHTIM IS SIMPLY THE TIME ELAPSED SINCE THE AGING RATE WAS LAST RECALCULATED.

DR(I,J) - DEATH RATE IN PROPORTION/UNIT TIME. (AGE,SEX)

DT - SIMULATION TIME INCREMENT IN TIME UNITS.

DTH(I,J) - DEATHS IN INDIVIDUALS/UNIT TIME. (AGE,SEX)

DT1 - THE LENGTH OF TIME BETWEEN THE PREVIOUS SIMULATION TIME (T-DT) AND THE SCHEDULED RECALCULATION OF THE AGING RATE. THIS VALUE WILL ALWAYS BE GREATER THAN ZERO AND LESS THAN DT.

DT2 - THE LENGTH OF TIME BETWEEN THE SCHEDULED RECALCULATION OF THE AGING RATE AND THE CURRENT TIME (T). THIS VALUE WILL ALWAYS BE GREATER THAN ZERO AND LESS THAN DT.

ICALL - MODE OF OPERATION OF THE COMPONENT. UNITLESS.

NC - NUMBER OF AGE COHORTS. UNITLESS.

NOBTH - INDICATES WHETHER BIRTHS ARE GENERATED BY THE POPULATION OR NOT. UNITLESS.

NSEX - NUMBER OF SEXES (OR SUBPOPULATIONS). UNITLESS.

PBF - PROPORTION OF BIRTHS WHICH ARE FEMALE (OR FIRST SUBPOPULATION).

PGRN - NATURAL GROWTH RATE OF THE POPULATION IN PERCENT/ UNIT TIME.

PGRT - ACTUAL GROWTH RATE OF THE POPULATION IN PERCENT/ UNIT TIME.

PLR(I,J) - PROPORTIONAL LOSS RATE (MIGRATION AND DEATHS) IN PROPORTION/UNIT TIME. (AGE,SEX)

PMR(I,J) - PROPORTIONAL MIGRATION RATE IN PROPORTION/UNIT TIME. (AGE,SEX)

POP(I,J) - POPULATION IN INDIVIDUALS. (AGE,SEX)

POPS(J) - TOTAL POPULATION BY SEX IN INDIVIDUALS. (AGE,SEX)

SR - SEX RATIO. UNITLESS.

T - SIMULATION TIME IN TIME UNITS.

TBTH - TOTAL BIRTHS IN INDIVIDUALS/UNIT TIME.

TDTH - TOTAL DEATHS IN INDIVIDUALS/UNIT TIME.

TMR - TOTAL MIGRATION RATE IN INDIVIDUALS/UNIT TIME.

TPOP - TOTAL POPULATION IN INDIVIDUALS.

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      DIMENSION AR(NC,NSEX), BR(NC), BTH(NSEX), COHLEN(NC,NSEX)
      DIMENSION DR(NC,NSEX), DTH(NC,NSEX), PLR(NC,NSEX)
      DIMENSION PMR(NC,NSEX), POP(NC,NSEX), POPS(NSEX)
C
C         DEMOGD IS DIVIDED IN TWO PARTS WHICH MAY BE CALLED SEPARATELY
C             IF ICALL=0 THE ENTIRE ROUTINE IS EXECUTED
C             IF ICALL=1 THE CURRENT POPULATION IS CALCULATED
C             IF ICALL=2 BIRTHS, DEATHS, MIGRATION, ETC. ARE CALCULATED
C
      IF(ICALL .GT. 1) GO TO 52
      TPOP = 0.
      DO 50 K=1,NSEX
        POPS(K) = 0.
        DO 40 J=1,NC
          COHTIM = AMOD(T, COHLEN(J,K))
          IF(COHTIM .GT. 0. .AND. COHTIM .LT. DT) GO TO 11
C
C         I. NORMALLY THE POPULATION IS CALCULATED FOR THE CURRENT TIME
C            AS FOLLOWS
C
          IF(T .EQ. 0.) GO TO 8
          IF(J .NE. 1) GO TO 2
          POP(1,K) = POP(1,K)*(1.-DT*PLR(1,K)) + DT*(BTH(K)-AR(1,K))
          GO TO 5
2         POP(J,K) = POP(J,K)*(1.-DT*PLR(J,K)) + DT*(ARP-AR(J,K))
5         ARP = AR(J,K)
          AR(J,K) = AR(J,K)*(1.-DT*PLR(J,K))
C
C             AT THE BEGINNING OF A NEW COHORT, A NEW MATURATION RATE
C             IS CALCULATED
C
8         IF(COHTIM .EQ. 0.) AR(J,K) = POP(J,K)/COHLEN(J,K)
          GO TO 26
C
C         II. IF THE SCHEDULED BEGINNING OF A NEW COHORT OCURRED DURING
C             THE PREVIOUS DT, THE POPULATION IS CALCULATED IN TWO
C             STEPS
C
C             1. THE POPULATION IS CALCULATED FOR THE BEGINNING OF
C                THE COHORT
C
11        DT1 = DT - COHTIM
          IF(J .NE. 1) GO TO 14
          POP(1,K) = POP(1,K)*(1.-DT1*PLR(1,K)) + DT1*(BTH(K)-AR(1,K))
          GO TO 17
14        POP(J,K) = POP(J,K)*(1.-DT1*PLR(J,K)) + DT1*(ARP-AR(J,K))
17        ART = AR(J,K)
          IF(POP(J,K) .LT. 0.) POP(J,K) = 0.
C
C                 THIS IS THE BEGINNING OF A NEW COHORT, SO A NEW
C                 MATURATION RATE IS CALCULATED
C
          AR(J,K) = POP(J,K)/COHLEN(J,K)
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C
C             2. THE POPULATION IS CALCULATED FOR THE CURRENT TIME
C
          DT2 = COHTIM
          IF(J .NE. 1) GO TO 21
          POP(1,K) = POP(1,K)*(1.-DT2*PLR(1,K)) + DT2*(BTH(K)-AR(1,K))
          GO TO 23
21        POP(J,K) = POP(J,K)*(1.-DT2*PLR(J,K)) + DT2*(ARP-AR(J,K))
23        ARP = (ARP*DT1 + AR(J,K)*DT2)/DT
          AR(J,K) = AR(J,K)*(1.-DT2*PLR(J,K))
26        IF(POP(J,K) .GT. 0.) GO TO 30
          POP(J,K) = 0.
          AR(J,K) = 0.
C
C         POPULATION TOTALS
C
30        POPS(K) = POPS(K) + POP(J,K)
40      CONTINUE
        TPOP = TPOP + POPS(K)
50    CONTINUE
      IF(ICALL .EQ. 1) RETURN
C
C         IF ICALL=1 EXECUTION ENDS HERE
C         IF ICALL=2 EXECUTION BEGINS HERE
C
C         MIGRATION AND DEATHS
C
52    TMR = 0.
      TDTH = 0.
      DO 54 K=1,NSEX
        DO 53 J=1,NC
          DTH(J,K) = DR(J,K)*POP(J,K)
C
C         THE OUTPUT OF THE LAST AGE COHORT IS CONSIDERED TO BE DEATHS
C
          IF(J .EQ. NC) DTH(J,K) = DTH(J,K) + AR(J,K)
          TDTH = TDTH + DTH(J,K)
          PLR(J,K) = PMR(J,K) + DR(J,K)
          TMR = TMR + PMR(J,K)*POP(J,K)
53      CONTINUE
54    CONTINUE
C
C         BIRTHS
C
C         IF BIRTHS ARE NOT COMPUTED FROM THE POPULATION (NOBTH=1)
C             THEN THE CALLING PROGRAM MUST SET TBTH TO THE DESIRED
C             NUMBER OF BIRTHS
C
      IF(NOBTH .EQ. 1) GO TO 65
      TBTH = 0.
      DO 55 J=1,NC
        TBTH = TBTH + BR(J)*POP(J,1)
55    CONTINUE
65    IF(NSEX .NE. 2) GO TO 68
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C
C          FOR TWO SEXES BIRTHS ARE APPORTIONED BETWEEN THEM ACCORDING
C              TO VARIABLE PBF
C
      BTH(1) = PBF*TBTH
      BTH(2) = TBTH - BTH(1)
      IF(POPS(1) .EQ. 0.) GO TO 70
      SR = POPS(2)/POPS(1)
      GO TO 75
C
C          FOR ONE SEX ALL BIRTHS GO TO THAT SEX AND SEX RATIO IS ZERO
C
68    BTH(1) = TBTH
70    SR = 0.
C
C          CRUDE BIRTH RATE, DEATH RATE, AND GROWTH RATES
C
75    IF(TPOP .EQ. 0.) GO TO 80
      CBR = TBTH/TPOP
      CDR = TDTH/TPOP
      PGRN = 100.*(CBR - CDR)
      PGRT = PGRN - 100.*TMR/TPOP
      RETURN
80    CBR = 0.
      CDR = 0.
      PGRN = 0.
      PGRT = 0.
      RETURN
      END
```

CLASS Documents

Number	Title
1	"Computer Library for Agricultural Systems Simulation: A Progress Report," Michael H. Abkin and Tom W. Carroll. (July 1976)
2	"Software Standards Manual." (July 1976)
3	"Policy Analysis Language, Version 2.3, Programmer's Guide for CDC Cyber Computers," Claudia S. Winer and Chris Wolf. (July 1976)
4	"Policy Analysis Language, Version 2.3, Reference Manual," Claudia S. Winer and Chris Wolf. (July 1976).
5	"Policy Analysis Language, Version 2.3, Guide to Using a PAL Program," Claudia S. Winer and Chris Wolf. (July 1976)
6	"DEMOGC: Demography with Distributed Age Cohorts," Michael H. Abkin and Chris Wolf. (July 1976)
7	"DEMOGD: Demography with Discrete Age Cohorts," Michael H. Abkin and Chris Wolf. (July 1976)
8	"Distributed Delay Routines: DEL, DELS, DELF, DELLF, DELVF, DELLVF," Michael H. Abkin and Chris Wolf. (July 1976)
9	"Table Functions: TABEL, TABEX, TABUL, TABUX," Michael H. Abkin, Chris Wolf, and Tom W. Carroll. (July 1976)
10	"AGACC: Accounting Routine for the Agricultural Sector," Dennis Pervis and Chris Wolf. (July 1976)
11	"User's Guide for the Beef Cattle Enterprise Simulation Model," Michael R. Jaske. (July 1976)
12	"User's Guide to SYSOPT: An Interactive System Optimization Computer Program," Marcus Buchner. (August 1976)