付録１）Adamsの操り返し計算のプログラム

```
ADAMS.FORT
       PROGRAM ADAMS
       IMPLICIT REAL*8 (A-H,J-Z)
       WRITE(6,601)
   601 FORMAT(1H1///1H0,'     THE SUCCESSIVE APPROXIMATION OF',-
       /'    IONIC CONCENTRATION AND ACTIVITIES',-
       /'          IN SOIL SOLUTIONS')
    10 READ(2,END=999)   I,CA,MG,NH4,K,CL,SO4,NO3
 "MOLER CONCENTRATION (MOLE/L)
       MCA =CA /40080.
       MMG =MG /24305.
       MK  =K  /39102.
       MNH4=NH4/14007.
       MCL =CL /35450.
       MSO4=SO4/96064.
       MNO3=NO3/14007.
       SCA =MCA
       SMG =MMG
       SK  =MK
       SNH4=MNH4
       SSO4=MSO4
       SNO3=MNO3
       I   = 1
 "IONIC STRENGTH
     1 MU  = (MCA*4.+MMG*4.+MK+MNH4+MCL+MSO4*4.+MNO3)/2.
 "ACTIVITY OF EACH ION
 "                      (MMOLE/L)
       ACA =MCA*COACT(MU,2.,6.)
       AMG =MMG*COACT(MU,2.,8.)
       AK  =MK *COACT(MU,1.,3.)
       ANH4=MNH4*COACT(MU,1.,2.5)
       ASO4=MSO4*COACT(MU,2.,4. )
       ANO3=MNO3*COACT(MU,1.,3. )
 "ION PAIR CONCENTRATION (MMOLE/L)
       CASO4 =ACA*ASO4/5.25
       MGSO4 =AMG*ASO4/5.88
       NH4SO4=ANH4*ASO4/79.3
       KSO4  =AK*ASO4/110.
       CANO3 =ACA*ANO3/525.
 "REVISED IONIC CONCENTRATIONS & IONIC STRENGTH (MMOLE)
       MMCA  =MCA*1000.
       MMMG  =MMG*1000.
       MMNH4 =MNH4*1000.
       MMK   =MK*1000.
       MMSO4 =MSO4*1000.
       MMCL  =MCL*1000.
       MMNO3 =MNO3*1000.
       A=DABS(SCA*1000.-(MMCA+CASO4))
       IF (A-0.0001) 3,3,2
     2 CONTINUE
       IF (I .GE. 100)  GO TO 3
       MCA =SCA -(CASO4+CANO3)*0.001
       MMG =SMG -MGSO4*0.001
       MNH4=SNH4-NH4SO4*0.001
       MK  =SK  -KSO4*0.001
       MSO4=SSO4-(CASO4+MGSO4+NH4SO4+KSO4)/1000.
       MNO3=SNO3 -CANO3/1000.
       I   = I+1
                            GO TO 1
     3 CONTINUE
         PPCA=MMCA*40.088
         PPMG=MMMG*24.305
         PPNH4=MMNH4*14.007
         PPK=MMK*39.102
         PPCL=MMCL*35.45
         PPSO4=MMSO4*96.064
         PPNO3=MMNO3*14.007
         WRITE(3) PPCA,PPMG,PPNH4,PPK,PPCL,PPSO4,PPNO3,CA,MG,NH4,K,CL,SO-
         4,NO3
                               GO TO 10
   999 STOP
       END
       FUNCTION COACT(MU,Z,AI)
 "ACTIVITY COEFFICIENTS
       IMPLICIT REAL*8 (A-H,M-Z)
       RMU  =DSQRT(MU)
       COACT=(1./10.**(0.509*Z**2*RMU/(1.+0.329*AI*RMU)))*1000.
       RETURN
       END
```

付録２）乾物生産とカリウム循環のモデルのプログラム(1)
（シミュレーション用プログラム BGS－1 のサブルーチン・プログラム）

```
      SUBROUTINE MODEL(MZ001)
C
C   K CYCLING MODEL     ***** URINATED AREA *****
C
      IMPLICIT      REAL*8  (A-H,O-Z)
      REAL*8   L,LST,LMF,LRI,LRV,MGME,N031,N032,N033,N034,N035,N03
     *         ,LRK,LRKS,MPRPDG,MPRPDL,MFG,MFL
      COMMON/GENERA/TIME,STIME,DT,FTIME,NY
      COMMON/D/DDM(10),DAK(7),DGRK(5),DLRK(5),DTODAY
      COMMON/V/DM(10),AK(7),GRK(5),LRK(5),TODAY
      COMMON/IC/DMS(10),AKS(7),GRKS(5),LRKS(5),TODAYS
      COMMON/PARAM/A(40),B(20),C(20)
      COMMON/TABLE/TABT(8),TABG(12)
     *               ,CL1(14),CL2(14),CL3(14),CL4(14),CL5(14)
     *               ,S041(14),S042(14),S043(14),S044(14),S045(14)
     *               ,N031(14),N032(14),N033(14),N034(14),N035(14)
     *               ,H201(14),H202(14),H203(14),H204(14),H205(14)
      COMMON/F/MFG(5),RIG(5),DG(5),RMFG(5),RRIG(5),RDG(5)
     *          ,MFL(5),RIL(5),DL(5),RMFL(5),RRIL(5),RDL(5)
     *          ,GRV(5),LRV(5),EK(5),BK(5)
     *          ,TOTLEK,TOTLBK,TOTLK,CKG,CKL
     *          ,SGMFGM,SGMFLM,SGRIGM,SGRILM,SGDGM,SGDLM,WDM,TTLGRK,TTLLRK
      DIMENSION   DGRV(5,1),DLRV(5,1),CL(5),S04(5),N03(5),DIFGRV(5),DIFLR
     *V(5),H20(5),FKGRB(5),FKLRB(5),RR(5),DD(5),CBK(5)
     *,MPRPDG(5),MPRPDL(5)
C
      DATA PAI/3.141592653D0/
     *,MGME/0.02558/,RDK/30.0/,LRI/0.0015/,GRI/0.0017/
     *,LMF/0.005/,GMF/0.005/,DD/2.875,3.10,3.425,3.925,4.225/
C
      GO TO (1000,2000,3000,4000),MZ001
 1000 CONTINUE
      NY     = 28
      RR(1)  = 0.44
      RR(2)  = 0.21
      RR(3)  = 0.13
      RR(4)  = 0.10
      RR(5)  = 0.12
      SGMFG  = 0.
      SGMFL  = 0.
      SGRIG  = 0.
      SGRIL  = 0.
      SGDG   = 0.
      SGDL   = 0.
C
 2000 CONTINUE
      CL(1)  = TABL1(CL1,  TIME)
      CL(2)  = TABL1(CL2,  TIME)
      CL(3)  = TABL1(CL3,  TIME)
      CL(4)  = TABL1(CL4,  TIME)
      CL(5)  = TABL1(CL5,  TIME)
      S04(1)= TABL1(S041,TIME)
      S04(2)= TABL1(S042,TIME)
      S04(3)= TABL1(S043,TIME)
      S04(4)= TABL1(S044,TIME)
      S04(5)= TABL1(S045,TIME)
      N03(1)= TABL1(N031,TIME)
      N03(2)= TABL1(N032,TIME)
      N03(3)= TABL1(N033,TIME)
      N03(4)= TABL1(N034,TIME)
      N03(5)= TABL1(N035,TIME)
      H20(1)= TABL1(H201,TIME)
      H20(2)= TABL1(H202,TIME)
      H20(3)= TABL1(H203,TIME)
      H20(4)= TABL1(H204,TIME)
      H20(5)= TABL1(H205,TIME)
      DO 280   N=1,10
  280 IF(DM(N) .LT.  0.1D-10)   DM(N)=0.1D-10
      DO 290   N=1,7
  290 IF(AK(N) .LT.  0.1D-10)   AK(N)=0.1D-10
      DO 300   I=1,5
      IF(GRK(I) .LT.  0.1D-10)   GRK(I)=0.1D-10
  300 IF(LRK(I) .LT.  0.1D-10)   LRK(I)=0.1D-10
      DO 110  I=1,5
      BK(I)  =  (A(40)+CL(I)*B( 3)+S04(I)*B(15)+N03(I)*B(16))*H20(I)
     1          /1000./MGME
```

乾物生産とカリウム循環のモデルのプログラム(2)

```
CCC    BK(I) : MGK/100CM**2   :   CL(I) ETC : ME/L   :   H2O(I) : ML/100CM**2
  110 CONTINUE
      DO 120 I=1,5
  120 EK(I) = BK(I)*RDK
CCC    EK(I) : MGK/100CM**2
      DO 210 I=1,5
      IF(BK(I) .LT. 0.1D-10) BK(I)=0.1D-10
      IF(EK(I) .LT. 0.1D-10) EK(I)=0.1D-10
  210 CONTINUE
      T1     = TABL1(TABT,TIME)
      TG     = TABL1(TABG,TIME)
      DS     = DSIN(PAI*TODAY/180.)
      STUR   = A(36) * DM(5)
      YIELD  = DM(1) + DM(3)
      ZERO   = 0.
      F12    = A(1)/(1.+DEXP(-A(2)*(TODAY-A(3))))
      F18    = A(5)*DEXP(A(6)*TODAY)
      F19    = A(7)+A(8)*T1
      F21    = A(9)*DS
      F28    = A(10)
      F29    = A(11)+A(12)*T1
      F34    = A(13)/(1.+ DEXP(-A(14)*(TODAY-A(15))))
      F38    = A(17)*DEXP(A(18)*TODAY)
      F39    = A(19)+A(20)*T1
      F43    = A(21)*DS
      F48    = A(22)
      F49    = A(23)+A(24)*T1
      F79    = A(27)+A(28)*T1
      F89    = A(29)+A(30)*T1
C     ST     = A(31)*DS+A(32)+A(39)
      ST     = 46.0+0.92*TODAY-0.0073*TODAY**2
      PG     = A(37)
      PL     = 1. - A(37)
      G      = A(38)
      L      = 1. - A(38)
      GST    = G * ST * A(34)
      LST    = L * ST * A(35)
      F57    = SWITCH(ZERO,A(25),TG)
      F59    = SWITCH(ZERO,A(26),TG)
C
      IF (YIELD - STUR)  2,1,1
    1 F15 = 0.
      F35 = 0.
      GT     = SWITCH(ZERO,A(33),TG)
      GO TO 3
    2 F15    = SWITCH(ZERO,A(4),TG)
      F35    = SWITCH(ZERO,A(16),TG)
      GT     = 0.
    3 CONTINUE
C
      FK1GR = B(1)/(1.+DEXP(-B(2)*(TODAY-A(3))))
      FK1BK = B(5)*DEXP(B(6)*TODAY)
      FK21  = B(8)   + B(7)*DS
      FK43  = B(10)  + B(9)*DS
      FK3BK = B(11)*DEXP(B(12)*TODAY)
      FK3LR = B(13)/(1.+DEXP(-B(14)*(TODAY-A(15))))
      FK6BK = B(19)
      FK7BK = B(20)
      FK56  = SWITCH(ZERO,B(17),TG)
      FK57  = SWITCH(ZERO,B(18),TG)
C
      CKG    = 100.*AK(1)/(DM(1))
      CKL    = 100.*AK(3)/(DM(3))
      GK     = B(4)*GT
C     IF (CKG .GT. 6.5) GST = GST*0.7
C     IF (CKL .GT. 6.5) LST = LST*0.7
      IF (CKG .GT. 6.5) FK21 = 0.
      IF (CKL .GT. 6.5) FK43 = 0.
C
      FK15  = F15
      FK35  = F35
      DO 140 I=1,5
      FKGRB(I)=C(I)
      FKLRB(I)=C(I+5)
  140 CONTINUE
      DO 150 I=1,5
      DIFGRV(I)=GRV(I)-DEADT(1,1.0,DGRV(I,1),GRV(I))
      DIFLRV(I)=LRV(I)-DEADT(1,1.0,DLRV(I,1),LRV(I))
  150 CONTINUE
```

乾物生産とカリウム循環のモデルのプログラム(3)

```
C
      DDM(1)= -(F12+F15+F18+F19)*DM(1)+F21*DM(2)+GST-PG*GT*DM(5)
      DDM(2)= F12*DM(1)-(F21+F28+F29)*DM(2)
      DDM(3)= -(F34+F35+F38+F39)*DM(3)+F43*DM(4)+LST-PL*GT*DM(5)
      DDM(4)= F34*DM(3)-(F43+F48+F49)*DM(4)
      DDM(5)= F15*DM(1)+F35*DM(3)-(F57+F59)*DM(5)+GT*DM(5)
      DDM(6)= 0.
      DDM(7)= F57*DM(5)-F79*DM(7)
      DDM(8)= F18*DM(1)+F28*DM(2)+F38*DM(3)+F48*DM(4)-F89*DM(8)
      DDM(9)= F19*DM(1)+F29*DM(2)+F39*DM(3)+F49*DM(4)+F59*DM(5)+F79*DM(7
     1)+F89*DM(8)
      DDM(10)=0.
C
      DAK(1)  = -(FK15+FK1GR+FK1BK)*AK(1)+FK21*(GRK(1)+GRK(2)+GRK(3)
     1          +GRK(4)+GRK(5))-PG*GK*DM(5)
      DAK(2)  = 0.
      DAK(3)  = -(FK35+FK3LR+FK3BK)*AK(3)+FK43*(LRK(1)+LRK(2)+LRK(3)
     1          +LRK(4)+LRK(5))-PL*GK*DM(5)
      DAK(4)  = 0.
      DAK(5)  = FK15*AK(1)+FK35*AK(3)-(FK56+FK57)*AK(5)+GK*DM(5)*0.2
      DAK(6)  = FK56*AK(5)-FK6BK*AK(6)
      DAK(7)  = FK57*AK(5)-FK7BK*AK(7)
C
      DO 130  I=1,5
          DIFG = DIFGRV(I)
          IF  (DIFG .LE. 0.) DIFG=0.
          DIFL = DIFLRV(I)
          IF  (DIFL .LE. 0.) DIFL=0.
CC
      CBK(I)   = BK(I)/H2O(I)
      MFG(I)   = GMF*DM(1)*RR(I)*CBK(I)
      RIG(I)   = GRI*DIFG**0.75
      DG(I)    = CBK(I)*DD(I)
      MPRPDG(I)=MFG(I)+RIG(I)+DG(I)
          IF  (MPRPDG(I)  .LT. 0.1D-10)  MPRPDG(I)=0.1D-10
      RMFG(I) = MFG(I)/MPRPDG(I)
      RRIG(I) = RIG(I)/MPRPDG(I)
      RDG(I)   =  DG(I)/MPRPDG(I)
      MFL(I)   = LMF*DM(3)*RR(I)*CBK(I)
      RIL(I)   = LRI*DIFL**0.75
      DL(I)    = CBK(I)*DD(I)
      MPRPDL(I)=MFL(I)+RIL(I)+DL(I)
          IF  (MPRPDL(I)  .LT. 0.1D-10)  MPRPDL(I)=0.1D-10
      RMFL(I) = MFL(I)/MPRPDL(I)
      RRIL(I) = RIL(I)/MPRPDL(I)
      RDL(I)   =  DL(I)/MPRPDL(I)
CC
         IF  (BK(I))  131,132,132
  131     MPRPDG(I)=0.1D-10
          MPRPDL(I)=0.1D-10
          BK(I)=0.1D-10
  132 CONTINUE
          IF  (CKG  .GT.  6.5)  MPRPDG(I)=0.1D-10
          IF  (CKL  .GT.  6.5)  MPRPDL(I)=0.1D-10
         BBGK = MPRPDG(I)+FK1GR*RR(I)*AK(1)
         BBLK = MPRPDL(I)+FK3LR*RR(I)*AK(3)
         IF  (FKGRB(I)  .GT.  0.001)  FKGRB(I)=0.1D-5
      DGRK(I) = BBGK
     *          -  (FKGRB(I)+FK21*RR(I))*GRK(I)
CC
      DLRK(I) = BBLK
     *          -  (FKLRB(I)+FK43*RR(I))*LRK(I)
  130 CONTINUE
      GMFG     = MFG(1)+MFG(2)+MFG(3)+MFG(4)+MFG(5)
      GMFL     = MFL(1)+MFL(2)+MFL(3)+MFL(4)+MFL(5)
      GRIG     = RIG(1)+RIG(2)+RIG(3)+RIG(4)+RIG(5)
      GRIL     = RIL(1)+RIL(2)+RIL(3)+RIL(4)+RIL(5)
      GDG      =  DG(1)+ DG(2)+ DG(3)+ DG(4)+ DG(5)
      GDL      =  DL(1)+ DL(2)+ DL(3)+ DL(4)+ DL(5)
      DTODAY=DT
```

乾物生産とカリウム循環のモデルのプログラム(4)

```
 3000 CONTINUE
      DO 180  N=1,10
  180 IF(DM(N)  .LT.  0.1D-10)   DM(N)=0.1D-10
      DO 190  N=1,7
  190 IF(AK(N)  .LT.  0.1D-10)   AK(N)=0.1D-10
      DO 200  I=1,5
      IF(GRK(I)  .LT.  0.1D-10)   GRK(I)=0.1D-10
  200 IF(LRK(I)  .LT.  0.1D-10)   LRK(I)=0.1D-10
      DO 160 I=1,5
      GRV(I)=DM(2)*RR(I)
      LRV(I)=DM(4)*RR(I)
  160 CONTINUE
C
           IF  (I .EQ. 1) GO TO 133
         BK(I)=BK(I)-MPRPDG(I)+FKGRB(I)*GRK(I)
     *              -MPRPDL(I)+FKLRB(I)*LRK(I)
                         GO TO 134
  133    BK(1)=BK(1)-MPRPDG(1)+FKGRB(1)*GRK(1)
     *              -MPRPDL(1)+FKLRB(1)*LRK(1)
     *              +FK6BK*AK(6)+FK7BK*AK(7)
  134 CONTINUE
C
      SGMFG    = SGMFG+GMFG
      SGMFL    = SGMFL+GMFL
      SGRIG    = SGRIG+GRIG
      SGRIL    = SGRIL+GRIL
      SGDG     = SGDG +GDG
      SGDL     = SGDL +GDL
C
          WDM  = DM(5)/0.15
C       DM(5)  = WDM
      TTLGRK   = GRK(1)+GRK(2)+GRK(3)+GRK(4)+GRK(5)
      TTLLRK   = LRK(1)+LRK(2)+LRK(3)+LRK(4)+LRK(5)
      TOTLEK   = EK(1)+EK(2)+EK(3)+EK(4)+EK(5)
      TOTLBK   = BK(1)+BK(2)+BK(3)+BK(4)+BK(5)
      TOTLK    = TOTLEK+TOTLBK
CCC   TOTLK ETC : MGK/100CM**2
 4000 CONTINUE
      SGMFGM   = SGMFG/30.
      SGMFLM   = SGMFL/30.
      SGRIGM   = SGRIG/30.
      SGRILM   = SGRIL/30.
      SGDGM    = SGDG /30.
      SGDLM    = SGDL /30.
      RETURN
      END
```

付録3）シミュレーションに使用したデータの1例 (1)

```
SIMTIME   ST   1.   DT   1.   FT   50.
METHOD    MD   0.
DATA
IC      28  1   100.  2   50.   3  100.   4 50.     5  135.   6  0.     7     .0
          8    0.  9     0. 10     0. 11  3.    12  0.    13  3.0   14     .0
         15    4.5 16     0. 17     0. 18 .22    19  0.105 20  0.065 21  0.005
         22  0.06  23    .22 24   .105 25 .065   26  .005  27  .006  28    1.0
PARAM   70  1 0.02    2 0.03    3 90.     4 0.5     5 0.015   6 0.001   7 0.0028
          8 0.0008  9 0.005  10 0.002  11 0.0014 12 .00042 13 0.02   14 0.03
         15 90.    16 0.5    17 0.015  18 0.001  19 0.0028 20 0.0008 21 0.0050
         22 0.002  23 0.0014 24 .00042 25 0.05   26 0.36   27 0.002  28 0.0020
         29 0.002  30 0.002  31 200.   32 10.0   33 0.4202 36 0.16   37 0.3300
         38 0.45   39 0.0    41 0.01   42 1.0    43 0.1437 45 0.015  46 0.0160
         47 .010   48 0.05   49 .0150  50 0.05   51 .015   52 .016   53 .01
         54 1.     55 0.1573 57 .0121  58 .0343  59 .121   60 .0121  61.001
         62.0005   63.0005   64.0005   65.0005   66.001    67.0005   68.0005
         69.0005   70.0005   44 .035   34 1.0    35 1.0    40-0.2982 56 .0586
TABLE    8  1     1.  2    6.8  3    10.  4    9.2  5    31.  6   11.0  7   50.0
          8   13.5
TABLE   12  9     1. 10     0. 11    45. 12     0. 13    46. 14  1.    15    50.
         16     1. 17    51. 18     0. 19   52.  20    0.
TABLE   14 21     1. 22 37.414 23     7. 24 23.324 25    14. 26  0.178 27   22.0
         28  0.079 29    28. 30  0.123 31    35. 32  0.181 33    50. 34  .0590
TABLE   14 35     1. 36  6.516 37     7. 38  8.022 39    14. 40  2.217 41   22.0
         42  4.601 43    28. 44  0.709 45    35. 46  0.350 47    50. 48  .1450
TABLE   14 49     1. 50  0.279 51     7. 52  1.379 53    14. 54  4.677 55   22.0
         56  4.746 57    28. 58  4.738 59    35. 60  1.299 61    50. 62 0.0590
TABLE   14 63     1. 64  0.226 65     7. 66  0.495 67    14. 68  3.731 69   22.0
         70  2.212 71    28. 72  2.086 73    35. 74  5.133 75    50. 76  6.765
TABLE   14 77     1. 78  0.220 79     7. 80  0.385 81    14. 82  0.855 83   22.0
         84  0.355 85    28. 86  1.089 87    35. 88  2.361 89    50. 90  5.450
TABLE   14 91     1. 92  15.11093     7. 94  7.918 95    14. 96  2.845 97   22.0
         98  1.044 99    28.100  0.121101    35.102  0.109103    50.104  0.109
TABLE   14105     1.106  0.591107     7.108  0.247109    14.110  1.178111   22.0
         112  2.265113    28.114  0.982115    35.116  0.985117    50.118  .5680
TABLE   14119     1.120  0.314121     7.122  0.202123    14.124  1.000125   22.0
         126  0.321127    28.128  1.833129    35.130  3.052131    50.132 3.7900
TABLE   14133     1.134  0.254135     7.136  0.283137    14.138  0.250139   22.0
         140  0.300141    28.142  0.086143    35.144  0.374145    50.146  .2640
TABLE   14147     1.148  0.163149     7.150  0.145151    14.152  0.083153   22.0
         154  0.466155    28.156  0.091157    35.158  0.188159    50.160  .2380
TABLE   14161     1.162  0.396163     7.164  0.316165    14.166  0.319167   22.0
         168  0.000169    28.170  0.016171    35.172  0.002173    50.174  .0510
TABLE   14175     1.176  0.328177     7.178  0.257179    14.180  0.557181   22.0
         182  0.024183    28.184  0.124185    35.186  0.015187    50.188 0.6760
TABLE   14189     1.190  0.004191     7.192  0.023193    14.194  0.416195   22.0
         196  0.004197    28.198  0.122199    35.200  0.000201    50.202 0.0000
TABLE   14203     1.204  0.164205     7.206  0.181207    14.208  0.081209   22.0
         210  0.000211    28.212  0.108213    35.214  0.015215    50.216 0.1550
TABLE   14217     1.218  0.320219     7.220  0.341221    14.222  0.124223   22.0
         224  0.002225    28.226  0.009227    35.228  0.004229    50.230  0.004
TABLE   14231     1.232    99.233     7.234   115.235    14.236   107.237   22.0
         238   106.239    28.240   111.241    35.242   109.243    50 244   99.0
TABLE   14245     1.246   123.247     7.248   124.249    14.250   143.251   22.0
         252   124.253    28.254   122.255    35.256   116.257    50.258  123.0
TABLE   14259     1.260   140.261     7.262   137.263    14.264   152.265   22.0
         266   142.267    28.268   137.269    35.270   126.271    50.272  140.0
TABLE   14273     1.274   149.275     7.276   157.277    14.278   164.279   22.0
         280   153.281    28.282   152.283    35.284   141.285    50.286  149.0
TABLE   14287     1.288   162.289     7.290   169.291    14.292   167.293   22.0
         294   167.295    28.296   147.297    35.298   152.299    50.300  162.0
EDATA
```

シミュレーションに使用したデータの１例 (2)

```
TITLE
     ***** DM PRODUCTION AND POTASSIUM CYCLE MODEL *****
RUNBGS
CONTBGS
SIMTIME             DT   1.   FT   80.
DATA
PARAM    6 34  1.5   35  0.9   40-.05508 43 .1652  55 .5798  56 .0973
TABLE    8  1    51.  2   14.3  3    60.  4   15.1  5    71.  6   17.3  7   80.0
            8   20.1
TABLE   12  9    51. 10     0. 11    75. 12     0. 13    76. 14  1.    15    80.
           16    1.  17    81. 18     0. 19   82.  20    0.
TABLE   14 21    51. 22 49.673 23    57. 24 46.150 25    64. 26  1.267 27   72.0
           28  0.329 29    78. 30  0.175 31    85. 32  0.264 33   100. 34  .0590
TABLE   14 35    51. 36 14.033 37    57. 38 11.804 39    64. 40  1.928 41   72.0
           42  2.213 43    78. 44  0.786 45    85. 46  0.337 47   100. 48 2.1710
TABLE   14 49    51. 50  2.471 51    57. 52  3.303 53    64. 54  9.067 55   72.0
           56  6.969 57    78. 58  3.220 59    85. 60  1.089 61   100. 62 18.443
TABLE   14 63    51. 64  1.588 65    57. 66  1.095 67    64. 68  8.871 69   72.0
           70  7.652 71    78. 72 11.528 73    85. 74  7.998 75   100. 76 18.871
TABLE   14 77    51. 78  1.627 79    57. 80  0.542 81    64. 82  3.664 83   72.0
           84  5.965 85    78. 86  6.751 87    85. 88  8.450 89   100. 90  9.476
TABLE   14 91    51. 92 35.831 93    57. 94 15.545 95    64. 96  1.941 97   72.0
           98  0.075 99    78.100  0.121101    85.102  0.135103   100.104  0.109
TABLE   14105    51.106  0.591107    57.108  3.130109    64.110  5.031111   72.0
          112  0.384113    78.114  1.140115    85.116  3.054117   100.118  .5680
TABLE   14119    51.120  0.314121    57.122  0.132123    64.124  3.587125   72.0
          126  1.604127    78.128  2.134129    85.130  3.196131   100.132 2.7400
TABLE   14133    51.134  0.254135    57.136  0.284137    64.138  0.433139   72.0
          140  0.050141    78.142  0.121143    85.144  0.124145   100.146  .0640
TABLE   14147    51.148  0.097149    57.150  0.094151    64.152  0.087153   72.0
          154  0.037155    78.156  0.091157    85.158  0.105159   100.160  .0790
TABLE   14161    51.162  0.396163    57.164  0.148165    64.166  2.123167   72.0
          168  1.275169    78.170  0.624171    85.172  0.144173   100.174  .0510
TABLE   14175    51.176  0.328177    57.178  0.525179    64.180  1.652181   72.0
          182  1.776183    78.184  0.895185    85.186  0.390187   100.188 4.8590
TABLE   14189    51.190  0.366191    57.192  0.084193    64.194  1.152195   72.0
          196  2.715197    78.198  2.005199    85.200  1.774201   100.202 6.4810
TABLE   14203    51.204  0.329205    57.206  0.079207    64.208  0.648209   72.0
          210  1.071211    78.212  2.506213    85.214  2.317215   100.216 6.2580
TABLE   14217    51.218  0.217219    57.220  0.356221    64.222  0.127223   72.0
          224  0.363225    78.226  0.552227    85.228  0.682229   100.230 4.6914
TABLE   14231    51.232    99.233    57.234   115.235    64.236   107.237   72.0
          238   106.239    78.240   111.241    85.242   109.243   100.244   99.0
TABLE   14245    51.246   123.247    57.248   124.249    64.250   143.251   72.0
          252   124.253    78.254   122.255    85.256   116.257   100.258  123.0
TABLE   14259    51.260   140.261    57.262   137.263    64.264   152.265   72.0
          266   142.267    78.268   137.269    85.270   126.271   100.272  140.0
TABLE   14273    51.274   149.275    57.276   157.277    64.278   164.279   72.0
          280   153.281    78.282   152.283    85.284   141.285   100.286  149.0
TABLE   14287    51.288   162.289    57.290   169.291    64.292   167.293   72.0
          294   167.295    78.296   147.297    85.298   152.299   100.300  162.0
EDATA
```

シミュレーションに使用したデータの１例 (3)

```
RUNBGS
CONTBGS
SIMTIME              DT      1.      FT   110.
DATA
PARAM        6 34   1.3     35   1.1     40-0.2982 43 .1437   55 .1573   56 .0586
TABLE        8  1     81.  2     20.1  3       90.  4     19.3  5      101.  6     18.6  7     110.0
                8     18.0
TABLE       12  9     81. 10       0. 11      105. 12       0. 13      106. 14       1.  15      110.
               16      1. 17     111. 18        0. 19    112. 20        0.
TABLE       14 21     81. 22 37.414 23       87. 24 23.324 25       94. 26  0.178 27     102.0
               28  0.079 29     108. 30    0.123 31     115. 32    0.181 33     130. 34     .0590
TABLE       14 35     81. 36  6.516 37       87. 38  8.022 39       94. 40  2.217 41     102.0
               42  4.601 43     108. 44    0.709 45     115. 46    0.350 47     130. 48     .1450
TABLE       14 49     81. 50  0.279 51       87. 52  1.379 53       94. 54  4.677 55     102.0
               56  4.746 57     108. 58    4.738 59     115. 60    1.299 61     130. 62    0.0590
TABLE       14 63     81. 64  0.226 65       87. 66  0.495 67       94. 68  3.731 69     102.0
               70  2.212 71     108. 72    2.086 73     115. 74    5.133 75     130. 76     6.765
TABLE       14 77     81. 78  0.220 79       87. 80  0.385 81       94. 82  0.855 83     102.0
               84  0.355 85     108. 86    1.089 87     115. 88    2.361 89     130. 90     5.450
TABLE       14 91     81. 92  15.11093       87. 94  7.918 95       94. 96  2.845 97     102.0
               98  1.044 99    108.100  0.121101    115.102  0.109103    130.104     0.109
TABLE       14105     81.106  0.591107      87.108  0.247109     94.110  1.178111     102.0
              112  2.265113    108.114  0.982115    115.116  0.985117    130.118     .5680
TABLE       14119     81.120  0.314121      87.122  0.202123     94.124  1.000125     102.0
              126  0.321127    108.128  1.833129    115.130  3.052131    130.132    3.7900
TABLE       14133     81.134  0.254135      87.136  0.283137     94.138  0.250139     102.0
              140  0.300141    108.142  0.086143    115.144  0.374145    130.146     .2640
TABLE       14147     81.148  0.163149      87.150  0.145151     94.152  0.083153     102.0
              154  0.466155    108.156  0.091157    115.158  0.188159    130.160     .2380
TABLE       14161     81.162  0.396163      87.164  0.316165     94.166  0.319167     102.0
              168  0.000169    108.170  0.016171    115.172  0.002173    130.174     .0510
TABLE       14175     81.176  0.328177      87.178  0.257179     94.180  0.557181     102.0
              182  0.024183    108.184  0.124185    115.186  0.015187    130.188    0.6760
TABLE       14189     81.190  0.004191      87.192  0.023193     94.194  0.416195     102.0
              196  0.004197    108.198  0.122199    115.200  0.000201    130.202    0.0000
TABLE       14203     81.204  0.164205      87.206  0.181207     94.208  0.081209     102.0
              210  0.000211    108.212  0.108213    115.214  0.015215    130.216    0.1550
TABLE       14217     81.218  0.320219      87.220  0.341221     94.222  0.124223     102.0
              224  0.002225    108.226  0.009227    115.228  0.004229    130.230     0.004
TABLE       14231     81.232     99.233     87.234    115.235     94.236    107.237     102.0
              238    106.239    108.240    111.241    115.242    109.243    130.244      99.0
TABLE       14245     81.246    123.247     87.248    124.249     94.250    143.251     102.0
              252    124.253    108.254    122.255    115.256    116.257    130.258     123.0
TABLE       14259     81.260    140.261     87.262    137.263     94.264    152.265     102.0
              266    142.267    108.268    137.269    115.270    126.271    130.272     140.0
TABLE       14273     81.274    149.275     87.276    157.277     94.278    164.279     102.0
              280    153.281    108.282    152.283    115.284    141.285    130.286     149.0
TABLE       14287     81.288    162.289     87.290    169.291     94.292    167.293     102.0
              294    167.295    108.296    147.297    115.298    152.299    130.300     162.0
EDATA
```

シミュレーションに使用したデータの1例 (4)

```
RUNBGS
CONTBGS
SIMTIME             DT   1.   FT  140.
DATA
PARAM    6 34  1.5   35  1.0   40-0.2982 43 .1437  55 .1573  56 .0586
TABLE    8  1   111.  2   18.0  3   120.  4   16.7  5   131.  6   15.0  7  140.0
            8   13.3
TABLE   12  9   111. 10     0. 11   135. 12     0. 13   136. 14     1. 15   140.
           16     1. 17   141. 18     0. 19   142. 20     0.
TABLE   14 21   111. 22 37.414 23   117. 24 23.324 25   124. 26  0.178 27  132.0
           28  0.079 29   138. 30  0.123 31   145. 32  0.181 33   160. 34  .0590
TABLE   14 35   111. 36  6.516 37   117. 38  8.022 39   124. 40  2.217 41  132.0
           42  4.601 43   138. 44  0.709 45   145. 46  0.350 47   160. 48  .1450
TABLE   14 49   111. 50  0.279 51   117. 52  1.379 53   124. 54  4.677 55  132.0
           56  4.746 57   138. 58  4.738 59   145. 60  1.299 61   160. 62 0.0590
TABLE   14 63   111. 64  0.226 65   117. 66  0.495 67   124. 68  3.731 69  132.0
           70  2.212 71   138. 72  2.086 73   145. 74  5.133 75   160. 76  6.765
TABLE   14 77   111. 78  0.220 79   117. 80  0.385 81   124. 82  0.855 83  132.0
           84  0.355 85   138. 86  1.089 87   145. 88  2.361 89   160. 90  5.450
TABLE   14 91   111. 92  15.11093   117. 94  7.918 95   124. 96  2.845 97  132.0
           98  1.044 99   138.100  0.121101   145.102  0.109103   160.104  0.109
TABLE   14105   111.106  0.591107   117.108  0.247109   124.110  1.178111  132.0
          112  2.265113   138.114  0.982115   145.116  0.985117   160.118  .5680
TABLE   14119   111.120  0.314121   117.122  0.202123   124.124  1.000125  132.0
          126  0.321127   138.128  1.833129   145.130  3.052131   160.132 3.7900
TABLE   14133   111.134  0.254135   117.136  0.283137   124.138  0.250139  132.0
          140  0.300141   138.142  0.086143   145.144  0.374145   160.146  .2640
TABLE   14147   111.148  0.163149   117.150  0.145151   124.152  0.083153  132.0
          154  0.466155   138.156  0.091157   145.158  0.188159   160.160  .2380
TABLE   14161   111.162  0.396163   117.164  0.316165   124.166  0.319167  132.0
          168  0.000169   138.170  0.016171   145.172  0.002173   160.174  .0510
TABLE   14175   111.176  0.328177   117.178  0.257179   124.180  0.557181  132.0
          182  0.024183   138.184  0.124185   145.186  0.015187   160.188 0.6760
TABLE   14189   111.190  0.004191   117.192  0.023193   124.194  0.416195  132.0
          196  0.004197   138.198  0.122199   145.200  0.000201   160.202 0.0000
TABLE   14203   111.204  0.164205   117.206  0.181207   124.208  0.081209  132.0
          210  0.000211   138.212  0.108213   145.214  0.015215   160.216 0.1550
TABLE   14217   111.218  0.320219   117.220  0.341221   124.222  0.124223  132.0
          224  0.002225   138.226  0.009227   145.228  0.004229   160.230  0.004
TABLE   14231   111.232    99.233   117.234   115.235   124.236   107.237  132.0
          238   106.239   138.240   111.241   145.242   109.243   160.244   99.0
TABLE   14245   111.246   123.247   117.248   124.249   124.250   143.251  132.0
          252   124.253   138.254   122.255   145.256   116.257   160.258  123.0
TABLE   14259   111.260   140.261   117.262   137.263   124.264   152.265  132.0
          266   142.267   138.268   137.269   145.270   126.271   160.272  140.0
TABLE   14273   111.274   149.275   117.276   157.277   124.278   164.279  132.0
          280   153.281   138.282   152.283   145.284   141.285   160.286  149.0
TABLE   14287   111.288   162.289   117.290   169.291   124.292   167.293  132.0
          294   167.295   138.296   147.297   145.298   152.299   160.300  162.0
EDATA
```

シミュレーションに使用したデータの１例 (5)

```
RUNBGS
CONTBGS
SIMTIME              DT    1.    FT   170.
DATA
PARAM      6 34    1.1 35    1.0 40-0.2982 43  .1437 55  .1573 56  .0586
TABLE      8  1   141.  2   13.3  3   150.  4   10.9  5   161.  6    9.0  7  170.0
              8    7.4
TABLE     12  9   141. 10     0. 11   165. 12     0. 13   166. 14     1. 15   170.
             16     1. 17   171. 18     0. 19   172. 20     0.
TABLE     14 21   141. 22 37.414 23   147. 24 23.324 25   154. 26  0.178 27  162.0
             28  0.079 29   168. 30  0.123 31   175. 32  0.181 33   190. 34  .0590
TABLE     14 35   141. 36  6.516 37   147. 38  8.022 39   154. 40  2.217 41  162.0
             42  4.601 43   168. 44  0.709 45   175. 46  0.350 47   190. 48  .1450
TABLE     14 49   141. 50  0.279 51   147. 52  1.379 53   154. 54  4.677 55  162.0
             56  4.746 57   168. 58  4.738 59   175. 60  1.299 61   190. 62 0.0590
TABLE     14 63   141. 64  0.226 65   147. 66  0.495 67   154. 68  3.731 69  162.0
             70  2.212 71   168. 72  2.086 73   175. 74  5.133 75   190. 76  6.765
TABLE     14 77   141. 78  0.220 79   147. 80  0.385 81   154. 82  0.855 83  162.0
             84  0.355 85   168. 86  1.089 87   175. 88  2.361 89   190. 90  5.450
TABLE     14 91   141. 92 15.11093   147. 94  7.918 95   154. 96  2.845 97  162.0
             98  1.044 99   168.100  0.121101   175.102  0.109103   190.104  0.109
TABLE     14105   141.106  0.591107   147.108  0.247109   154.110  1.178111  162.0
            112  2.265113   168.114  0.982115   175.116  0.985117   190.118  .5680
TABLE     14119   141.120  0.314121   147.122  0.202123   154.124  1.000125  162.0
            126  0.321127   168.128  1.833129   175.130  3.052131   190.132 3.7900
TABLE     14133   141.134  0.254135   147.136  0.283137   154.138  0.250139  162.0
            140  0.300141   168.142  0.086143   175.144  0.374145   190.146  .2640
TABLE     14147   141.148  0.163149   147.150  0.145151   154.152  0.083153  162.0
            154  0.466155   168.156  0.091157   175.158  0.188159   190.160  .2380
TABLE     14161   141.162  0.396163   147.164  0.316165   154.166  0.319167  162.0
            168  0.000169   168.170  0.016171   175.172  0.002173   190.174  .0510
TABLE     14175   141.176  0.328177   147.178  0.257179   154.180  0.557181  162.0
            182  0.024183   168.184  0.124185   175.186  0.015187   190.188 0.6760
TABLE     14189   141.190  0.004191   147.192  0.023193   154.194  0.416195  162.0
            196  0.004197   168.198  0.122199   175.200  0.000201   190.202 0.0000
TABLE     14203   141.204  0.164205   147.206  0.181207   154.208  0.081209  162.0
            210  0.000211   168.212  0.108213   175.214  0.015215   190.216 0.1550
TABLE     14217   141.218  0.320219   147.220  0.341221   154.222  0.124223  162.0
            224  0.002225   168.226  0.009227   175.228  0.004229   190.230  0.004
TABLE     14231   141.232    99.233   147.234   115.235   154.236   107.237  162.0
            238   106.239   168.240   111.241   175.242   109.243   190.244   99.0
TABLE     14245   141.246   123.247   147.248   124.249   154.250   143.251  162.0
            252   124.253   168.254   122.255   175.256   116.257   190.258  123.0
TABLE     14259   141.260   140.261   147.262   137.263   154.264   152.265  162.0
            266   142.267   168.268   137.269   175.270   126.271   190.272  140.0
TABLE     14273   141.274   149.275   147.276   157.277   154.278   164.279  162.0
            280   153.281   168.282   152.283   175.284   141.285   190.286  149.0
TABLE     14287   141.288   162.289   147.290   169.291   154.292   167.293  162.0
            294   167.295   168.296   147.297   175.298   152.299   190.300  162.0
EDATA
```

シミュレーションに使用したデータの1例 (6)

```
RUNBGS
OUTPUT
GRAPH     INTV    1.STIM    1.FTIM  170.
VARIABLE 7TOPG V   1MARKG    ULMT  1400LLMT  0.
VARIABLE  ROTG V   2MARKI    ULMT  1400LLMT  0.
VARIABLE  TOPL V   3MARKL    ULMT  1400LLMT  0.
VARIABLE  ROTL V   4MARKM    ULMT  1400LLMT  0.
VARIABLE  HEFR F  92MARKH    ULMT  1400LLMT  0.
VARIABLE  DUNG V   7MARKD    ULMT  1400LLMT  0.
VARIABLE  LITR V   8MARKF    ULMT  1400LLMT  0.
GRAPH     INTV    1.STIM    1.FTIM  170.
VARIABLE 5AK1  V  11MARK1    ULMT  60. LLMT  0.
VARIABLE  AK3  V  13MARK3    ULMT  60. LLMT  0.
VARIABLE  AK5  V  15MARK5    ULMT  15. LLMT  0.
VARIABLE  AK6  V  16MARK6    ULMT  5.  LLMT  0.
VARIABLE  AK7  V  17MARK7    ULMT  5.  LLMT  0.
GRAPH     INTV    1.STIM    1.FTIM  170.
VARIABLE 5GRK1 V  18MARK1    ULMT  35. LLMT  0.
VARIABLE  GRK2 V  19MARK2    ULMT  35. LLMT  0.
VARIABLE  GRK3 V  20MARK3    ULMT  35. LLMT  0.
VARIABLE  GRK4 V  21MARK4    ULMT  35. LLMT  0.
VARIABLE  GRK5 V  22MARK5    ULMT  35. LLMT  0.
GRAPH     INTV    1.STIM    1.FTIM  170.
VARIABLE 5LRK1 V  23MARK1    ULMT  35. LLMT  0.
VARIABLE  LRK2 V  24MARK2    ULMT  35. LLMT  0.
VARIABLE  LRK3 V  25MARK3    ULMT  35. LLMT  0.
VARIABLE  LRK4 V  26MARK4    ULMT  35. LLMT  0.
VARIABLE  LRK5 V  27MARK5    ULMT  35. LLMT  0.
GRAPH     INTV    1.STIM    1.FTIM  170.
VARIABLE 2GRK  F  93MARKG    ULMT  70. LLMT  0.
VARIABLE  LRK  F  94MARKL    ULMT  70. LLMT  0.
GRAPH     INTV    1.STIM    1.FTIM  170.
VARIABLE 2CKG  F  84MARKG    ULMT  10. LLMT  0.
VARIABLE  CKL  F  85MARKL    ULMT  10. LLMT  0.
GRAPH     INTV    1.STIM    1.FTIM  170.
VARIABLE 5BK1  F  76MARK1    ULMT  150.LLMT  0.
VARIABLE  BK2  F  77MARK2    ULMT  30. LLMT  0.
VARIABLE  BK3  F  78MARK3    ULMT  30. LLMT  0.
VARIABLE  BK4  F  79MARK4    ULMT  30. LLMT  0.
VARIABLE  BK5  F  80MARK5    ULMT  30. LLMT  0.
PRINT     INTV    1.STIME   1.FTIM  170.TITL    1.
VARIABLE 7TOPG V   1ROTG V   2TOPL V   3ROTL V   4HEFR F  92DUNG V   7LITR V   8
PRINT     INTV    1.STIME   1.FTIM  170.TITL    1.
VARIABLE 5AK1  V  11AK3  V  13AK5  V  15AK6  V  16AK7  V  17
PRINT     INTV    1.STIME   1.FTIM  170.TITL    1.
VARIABLE 5BK1  F  76BK2  F  77BK3  F  78BK4  F  79BK5  F  80
EOUTPUT
ENDBGS
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Studies on Evaluation of Heifer Excreta Contribution on Grazing Pasture Fertility

by

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SUMMARY

The purpose of the studies was to obtain information for the development of rational fetilization methods for grazing pasture 1) by analysing the characterisitics of the nutrient cycling system of grazing pasture, 2) by constructing system models, and 3) by determining the contribution of heifer excreta to pasture fertility.

§ 1. Nutrient cycling on grazing pasture

Fertilizer management should be rationalized based on the knowledge of nutrient cycling. In Japan, however, nutrient cycling in a pasture has been little investigated from the view point of the relation between soil, plant and cattle, because a convenient method by which subsystems and/or the pathway of the cycle can be combined as a pasture system has not been developed. This study was initiated to desingn a mathematical system model aimed of representing the verious aspects of nutrient cycling in a grazing pasture.

The improvement of grassland productivity by fertilization was discussed in considering the nitrogen (N), phosphorus (P) and potassium (K) cycles.

The results obtained were as follows:

1) In a grazing experiment on volcanic ash soil in the Nemuro district, Hokkaido, N–P–K fertilization improved the productivity of herbage yield and heifer growth compared with only K fertilizaition.

2) In the N–P–K cycles, i) the cycling nutrients were mainly affected by standing crop, ii) the nutrients removed amounted to 14–16% (N); 3.5–4% (P) and 12–14% (K) of the cycling nutrients and iii) the rate of nutrients returned to soil as excreta was N, 46–53%; P, 58–65% and K, 47–55%.

3) It is concluded that N–P–K fertilization removes the limiting factor associated with a low P supply, meets of the vequivements for N and compensates for the loss of the fertilizing effect of excreta in case of patchily aggregated return.

4) The patchy aggregation of nutrients should be analysed to identify precisely the contribution of nutrient cycling to pasture and to evaluate the fertility effect of heifer excreta.

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§2. Excreta dispersion models and conditions of application

The dispersion characteristics of heifer excreta on a pasture were investigated and analyzed quantitatively. Dispersion patterns were examined by fitting the theoretical distributions to the observed excreta frequency distributions and by using the MORISITA's I_δ-index. The results obtained are as follows:

1) Most of the excreta clumps occupying a 2 — 8a quadrat were associated with the use of grazing equipment, e.g., watering points and salt racks. Excreta dispersion including these clumps was more aggregated, but less aggregated when the clumps were removed.

2) Frequency distribution of excreta per quadrat was represented by the Poisson or negative binomial models after the clumps associated with the use of grazing equipment were removed.

3) When a significant number of clumps associated with the use of grazing equipment was removed, the conditions of application of the two kinds of models were divided into three groups based on the relationship between the quadrat size and the mean density of dung and urine, and the 'common *k*' of the negative binomial model estimated for dung was 4.40 (confidence limits: 4.00—4.88).

§3. Simulation studies on uneven excreta dispersion associated with a grazing equipment

The dispersion of heifer excreta in a flat and square pasture (1 ha) surrounded by fences with a watering point at one edge was examined, and the relationships between the excreta density of a site and its distance from the watering point were derived as decreasing exponential functions. Dispersion patterns of dung and urine in a pasture with the same phape as the field previously described were simulated by using the above mentioned relationships to define the formation process of excreta dispersion. It was shown that grazing equipment, e.g., watering points, causes uneven excreta dispersion, and that, when the spatially biased densities are formulated mathematically, the uneven dispersion of excreta can be represented by the Poisson model.

§4. Nutrient movement in soils to which heifer urine is or is not applied

A lysimeter experiment was conducted during a period of 36 days to determine the content and distribution of ions in a soil solution. Three factors were considered: urine *vs.* no urine; anion froms, chloride (Cl) *vs.* sulphate (SO_4); and planted *vs.* bare soil.

1) The results indicate that Cl in the soil solution moved downward more slowly SO_4, and that the nitrate (NO_3) concentration increased at all levels with time. By comparison, monovalent cations (K and NH_4) remained in the upper three layers (0 —15cm) and divalent cations (Ca and Mg) in the soil solution moved into the lower layers (10—25cm) with time.

2) The multiple regression analyses showed that the amount of K present in the soil solution is mainly controlled by the concentration of the anions and that NH_4 concentration is controlled by the Cl and SO_4 levels. In addition, K and NH_4 contents are regulated by the corresponding contents of exchangeable cations. Divalent cations are present in such proportions that electroneutrality is balanced, although

their contens are controlled by those of Cl and NO_3 to a certain extent.

3) Canonical correlation analysis showed that the 1st two canonical variates are positively and highly correlated with the concentration of each ion, and are considered to be weighted means of anion and cation concentrations. Summation of the respective anions or cations multipilied by the weights indicated a high correlation among them. This relationship may reflect accurately the electroneutrality in a soil solution.

§5. Release and transfer of nutrients from heifer dung to soil and forage

The release and transfer of N–P–K from heifer dung to plant and soil was studied in order to evalutae the effects of heifer dung on soil fertillity and plant growth.

1) Fresh dung contained relatively high levels of the water soluble fraction of N–P–K which was released rapidly. In contrast, after 30—40 days dung released N–P–K slowly. Potassium present mostly in the water soluble fraction was readily released and leached into the deeper soil layers. However, in dried dung, K was retained and was released slowly during three months. The level of the water soluble fractions of N and P in the soil was lower, and the release of N and P was associated with dung decomposition. Most of the N and P that was released did not leach into the lower soil layers, but was retained in the surface soil immediately beneath the dung pile.

2) Forms of N–P–K in the soil after release: N was mostly present as nitrate; after 30—40 days the soil contained large amounts of P soluble in 2.5% acetic acid; while K was present first in water soluble form and then in the exchangeable form. The exchangeable form of K was mainly present in the soil under the dung compared with virgin soil.

3) Forage growing inside a radius of 50cm from the center of the dung pile contained very high levels of N and K.

§6. Persistence of the effect of patchily aggregated reduced excreta

"Fertility effect" of excreta refers to the ratio of the plots where excreta are applied to the plots where no application was made, in relation to the content of the nutrients and yields.

1) A large quantity of N is contained in the dung and urine, but its fertility effect is not clear. K in dung and urine affected rapidly and significantly the K content in the pasture plants, whereas K in dung only lost its effect rapidly. A comparatively large quantity of Ca is contained in the dung, but its effect is related to the activity of K. The effect of P and Mg in the dung was comparatively significant and durable. Since Mg shows a strong antagonism against K in the absorption by grass plant, the effect of Mg became apparent when the effect of K decreased.

2) As for the characteristics of the effect of excreta on yield, it was observed that urine increased clover yield and decreased grass yield, and that dung in particuler increased the yield of these plants in July of each year.

3) The effect of the excreta, particularly on the K content, persisted until August of the fourth year in the longest case. The duration of the effect (more than three full years) ranks as the longest in the results ever reported.

§7. Dynamic model of dry matter production and K cycling in grazing pasture

K cycling model consisted of two subsystems related to dry matter production and K transport process. In this model, dry matter of grass or legume is produced in proportion to the average comparative growth rate (CGR) in eastern Hokkaido and is distributed into the tops and roots of herbage, a part of which being dead. When heifers are introduced into a pasture, they eat some portions of top and excrete them. K distributes from the solution phase to exchangeable sites and *vice versa* in five soil layers in this model. The amount of K which is absorbed by plant roots from the soil solution is proportional to the amount of top dry matter multiplied by K concentration in the solution, to the increament of the surface area of root and to the amount of K in the soil solution. K is transported reversibly to the roots and tops. A part of K is grazed by heifer and a part of it is excreted as urine or dung. K concentration of top affects dry matter production.

These processes can be described by 23 differential equations. Parameters in this model are determined on an experimental and empirical basis.

Herbage production and K uptake in a growing season were simulated by using the two models.

§8. Evaluation of excreta contribution on pasture fertility by simulation studies

1) Two system models (the K cycling model described previously and the excreta spatial dispersion model described in § 3) were constructed to determine how biased dispersion of K and herbage yields occurs in a pasture. Eighteen conditions [(no excretion + (urine, dung) × 4 excreted months) × (grass + legume)] were simulated by the K cycling model to define the standing crops of K and herbage at the end of a growing season. The standing crops per 1 m^2 were calculated in all the quadrats in the pasture by using the excreta dispersion model. The standing crops in each of the 18 cases were assumed to be normally distributed.

2) The frequency distributions of absorbed K and herbage yields on the whole paddock deviated from the normal distribution, but extreme variations and biases which are observed in a pasture were not recorded. This finding indicates that the non–normal distribution of K accumulation is reflected in the process of its cycling through cattle, especially urine, soil and herbage which are structured in the cycling model. The non–normal dispersion of herbage yields actually observed is contributed by the fertility effect simulated above, as well as by the lack of residual herbage associated with the grazing behavior of cattle.

3) This suggested that these system models which were constructed on the basis of observation and experiments in this study may account for the process of nutrient cycling and excreta effects on pasture fertility.