DSSAT v4.7 – Automatic Irrigation using Growth Stage Controls

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With the release of DSSAT v4.7, CSM now has the capability of controlling automatic irrigation using growth stages. This is done through the Simulation Controls section of FileX. Box 1 shows a sample set of irrigation controls using growth stage controlled automatic irrigation, used to demonstrate the capabilities in this document.

Box 1. Simulation controls for growth stage controlled automatic irrigation

```
*SIMULATION CONTROLS
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................... SMODEL
 4 GE              1     1     S 82056  2150 N X IRRIGATION, GAINESVI
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 4 OP              Y     Y     N     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 4 ME              M     M     E     R     S     R     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 4 MA              R     A     R     N     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 4 OU              N     Y     Y     1     Y     N     Y     Y     N     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 4 PL          82050 82064    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IRON  IMETH IRAMT IREFF AVWAT IFREQ AIName
 4 IR             20    50    90 GS007 IR004   -99     1   200     7 Sowing date
 4 IR             30    50    90 GS002 IR004   -99     1   -99     7 Floral initiation
 4 IR             30    60   100 GS004 IR004   -99     1   -99     7 Grain filling
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 4 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 4 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 4 HA              0 83057   100     0
```

The IRRIG switch is set to “A” or “F” for automatic with computed (“A”) or with fixed (“F”) amounts, as in previous versions of CSM. The automatic irrigation section now allows multiple lines, each corresponding to the beginning of a growth stage listed in the IRON (irrigation on) column. The growth stages depend on the crop being simulated at the time, and are listed in the GRSTAGE.CDE file. For example, Box 2 lists the growth stages for Ceres Maize from the GRSTAGE.CDE file. In the sample simulation controls in Box 1, the first line of controls begins at growth stage 7, sowing date; the second set of controls begins at growth stage 2, floral initiation; and the final set of controls begins at growth stage 4, R2 or grain filling.

Caution! GRSTAGE.CDE may not be completely up to date for all crops! Be sure to check your outputs carefully to make sure that you are getting the irrigation timing that you expect.

Box 2. Growth stages for maize from GRSTAGE.CDE file

```
*Growth and Development Codes - Maize (CERES Version 4.5)
! Ritchie and Hanway, 1982
@CDE  NAME  DESCRIPTION..................................................... SYNONYMS
GS000       None                                                            .
GS009 VE    50% of plants with some part visible at soil surface            .
      V1    50% of plants with collar of 1st leaf visible                   .
      V2    50% of plants with collar of 2nd leaf visible                   .
      Vn    50% of plants with collar of nth leaf visible                   .
      VT    50% of plants with last branch of tassel visible,silks not visible   .
GS003 R1    50% of plants with some silks visible outside husks             .
GS004 R2    50% of plants in blister stage                                  .
      R3    50% of plants in milk stage                                     .
      R4    50% of plants in dough stage                                    .
      R5    50% of plants in dent stage                                     .
GS005 R6    50% of plants at physiological maturity                         .
GS006 R7    50% of plants harvest maturity                                  .
GS007       Sowing date                                                     .
GS001       End of juvenile phase                                           .
GS002       50% of plants completed floral initiation                       .
GS008       50% of plants germinated                                        .
```

In each set of growth stage controls, the following variables can be set:

- IMDEP – irrigation management depth (cm)
- ITHRL – lower threshold of available water to trigger an irrigation event (%)
- **ITHRU – upper threshold of available water to calculate irrigation amount (for IRRIG = "A")**
- **IRON – growth stage at which irrigation rules are switched on**
- IMETH – irrigation method
- IRAMT – irrigation amount (mm, for IRRIG = 'F')
- IREFF – irrigation efficiency (%)
- **AVWAT – available water (mm)**
- **IFREQ – minimum number of days between irrigation events**

Variables IMDEP, ITHRL, IMETH, IRAMT, and IREFF function exactly as they did in previous version of the automatic irrigation routines. Variable ITHRU, and IRON were previously available in Simulation Controls, but not used in the model. Two new variables are AVWAT and IFREQ.

ITHRU allows a deficit irrigation amount to be calculated when using the "A" option. Previously, the model computed the amount of irrigation needed to fill the soil profile to 100% of available water. Now the model uses ITHRU to set the soil water content after an irrigation event.

IRON allows the user to specify different automatic irrigation rules depending on growth stage. The rules take effect at the beginning of the IRON growth stage and continue until rules are changed by another entry. The last set of rules specified are in effect until the end of simulation.

AVWAT is used to limit irrigation when water resources are scarce. It can be set separately for each growth stage. If only the first growth stage has a positive value of AVWAT, then this amount is used to limit the available

source water for irrigation for the entire season. If "-99" or blank values are provided for any growth stage, then source water for irrigation is assumed to be unlimited, as in previous versions of the model.

IFREQ is used to limit the frequency of irrigation, as in a center pivot irrigation system. The variable can be input as a real number, but is rounded to the nearest integer for comparison with the number of days since the previous irrigation application.

When using growth stage irrigation, it is important to look at the outputs in detail for at least one season to check that the irrigation events are done correctly. The best way to do this is to switch on the MgmtEvents.OUT file using the OPOUT switch in Simulation Controls (see Box 1 for switch).

The MgmtEvents.OUT file shown in Box 3 was created using the FileX controls in Box 1 with the DSSAT experiment UFGA8201.MZX as a base. In this example, no irrigation was added until after floral initiation because sufficient rainfall maintained soil water content above the lower threshold (ITHRL) within the management depth (IMDEP). The irrigation amount between floral initiation and grain filling is limited by the 50 mm of available water specified for Growth Stage 2 (AVWAT). The amount of irrigation is computed based on the soil water deficit within the management depth and the user-specified upper threshold for filling the soil profile (ITHRU). The frequency of irrigation (IFREQ) during this time period was limited to once per week. At the beginning of grain filling, one irrigation application was made. After that time, rainfall was sufficient to maintain soil moisture above the lower threshold until maturity and harvest.

Box 3. Output in MgmtEvents.OUT file showing the results of using growth stage-controlled irrigation

```
*DSSAT Cropping System Model Ver. 4.7.1.006 -develop      OCT 24, 2018; 14:30:58
!-------------------------------------------------------------------------------------------
@RUN Date.........  DOY    DAS    DAP  CR  Stage         Operation       Quantities
!-------------------------------------------------------------------------------------------
   5 FEB 25, 1982  056      1      0  MZ  14 Start Sim
   5 FEB 26, 1982  057      2      0  MZ  07 Sowing
   5 FEB 27, 1982  058      3      1  MZ  08 Germinate
   5 MAR  9, 1982  068     13     11  MZ  09 Emergence
   5 MAR 15, 1982  074     19     17  MZ                Fertilizer         56. kg[N]/ha
   5 MAR 27, 1982  086     31     29  MZ  01 End Juveni
   5 MAR 30, 1982  089     34     32  MZ                Fertilizer         52. kg[N]/ha
   5 APR  1, 1982  091     36     34  MZ  02 Floral Ini
   5 APR  5, 1982  095     40     38  MZ                Irrigation        13.1 mm
   5 APR 12, 1982  102     47     45  MZ                Fertilizer         75. kg[N]/ha
   5 APR 17, 1982  107     52     50  MZ                Irrigation        13.0 mm
   5 APR 24, 1982  114     59     57  MZ                Irrigation        19.2 mm
   5 APR 28, 1982  118     63     61  MZ                Fertilizer         37. kg[N]/ha
   5 MAY  2, 1982  122     67     65  MZ                Irrigation         4.8 mm
   5 MAY  7, 1982  127     72     70  MZ                Fertilizer         55. kg[N]/ha
   5 MAY 13, 1982  133     78     76  MZ  03 75% Silkin
   5 MAY 17, 1982  137     82     80  MZ                Fertilizer        126. kg[N]/ha
   5 MAY 24, 1982  144     89     87  MZ  04 Beg Gr Fil
   5 JUN  7, 1982  158    103    101  MZ                Irrigation        13.5 mm
   5 JUL  1, 1982  182    127    125  MZ  05 End Gr Fil
   5 JUL  3, 1982  184    129    127  MZ  Phys. Maturity
   5 JUL  3, 1982  184    129    127  MZ  16 Harvest
   5 JUL  3, 1982  184    129    127  MZ                Harvest Yield    1934. kg/ha
```

Caution! Currently, the XBuild user interface for entering experimental data does not handle growth stage irrigation inputs. If you want to use this feature, you must create your simulation controls in a text editor or by some automated program. Experiment files with growth stage irrigation routines should not be opened with XBuild because the new variables will be deleted when saving the file. We are working on updating XBuild to handle this new model capability.

ET-based automatic irrigation routines

Automatic irrigation rules can also be set using evapotranspiration as a trigger. In this case, the IRRIG switch is set to "E" for automatic irrigation using a calculated amount and "T" uses a fixed irrigation amount. Most of the user inputs in the Simulation Controls section of FileX are identical to other methods of automatic irrigation, except the IMDEP and ITHRU variables. When the "E" or "T" options are used, **IMDEP** represents the threshold accumulation of ET which triggers an irrigation event. Variable **ITHRU** can be used to set a deficit amount of irrigation. It is expressed as a percentage of the accumulated ET that will be applied as irrigation. The default is 100%. Variable ITHRL is not used, but other variables have the same functions as previously described herein.

Box 4 shows sample inputs using the "E" and "T" options for automatic irrigation. Simulation controls section 6 shows the "E" option, where the irrigation amount is calculated from an accumulation of ET minus rainfall. When an irrigation event is triggered, only 90% of the accumulated ET will be applied.

Simulation controls section 7 uses the "T" option, where fixed amounts of irrigation are specified in the IRAMT variable.

ET-based automatic irrigation algorithm:

1. Every day, accumulate potential transpiration (EOP) plus evaporation (EVAP), minus infiltration (RAIN - RUNOFF).
2. If the accumulated ET is greater than the user-specified threshold (IMDEP), an irrigation event is triggered.
3. For ET option "E", the irrigation amount is computed as the accumulated ET reduced by the deficit irrigation amount (ITHRU).
4. For option "T", a fixed irrigation amount (IRAMT) is applied.

Still to be done:

- Update GRSTAGE.CDE for consistency with model terminology for each CROP-MODEL combination.
- Modify XBuild to allow users to input multiple growth stage automatic irrigation inputs.

Box 4. ET-based automatic irrigation inputs

```
! Auto irrigation triggered by ET demand. Irrigation amounts = ET demand (IRRIG = 'E')
!   When ET exceeds IMDEP, an irrigation event is triggered.
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................. SMODEL
 6 GE              1     1     S 82056  2150 Auto-irr fix, GS, WL
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 6 OP              Y     Y     N     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 6 ME              M     M     E     R     S     R     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 6 MA              R     E     R     N     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 6 OU              N     Y     Y     1     Y     N     Y     Y     N     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 6 PL          82050 82064    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IRON  IMETH IRAMT IREFF AVWAT IFREQ AIName
 6 IR             10   -99    90 GS007 IR004   -99     1    20     5 Sowing date
 6 IR             15   -99    90 GS002 IR004   -99     1   100     5 Floral initiation
 6 IR              5   -99    90 GS004 IR004   -99     1   100     5 Grain filling
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 6 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 6 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 6 HA              0 83057   100     0

! Auto irrigation triggered by ET demand. Fixed irrigation amounts (IRRIG = 'T')
!   When ET exceeds IMDEP, an irrigation event is triggered.
!   Irrigation amount set by IRAMT.
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME.................. SMODEL
 7 GE              1     1     S 82056  2150 Auto-irr fix, GS, WL
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES  CHEM  TILL   CO2
 7 OP              Y     Y     N     N     N     N     N     Y     M
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO HYDRO NSWIT MESOM MESEV MESOL
 7 ME              M     M     E     R     S     R     R     1     G     S     2
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 7 MA              R     T     R     N     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT VBOSE CHOUT OPOUT
 7 OU              N     Y     Y     1     Y     N     Y     Y     N     N     Y     N     Y

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 7 PL          82050 82064    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IRON  IMETH IRAMT IREFF AVWAT IFREQ AIName
 7 IR             10   -99   -99 GS007 IR004    10     1    20     5 Sowing date
 7 IR             15   -99   -99 GS002 IR004    20     1   100     5 Floral initiation
 7 IR              5   -99   -99 GS004 IR004    25     1   100     5 Grain filling
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 7 NI             30    50    25 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 7 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 7 HA              0 83057   100     0
```