

Supplementary Material: A Guide for Using the Coupled SWAT–MODSIM (SM) Model

Saeid Ashraf Vaghefi (saeedashrafv@gmail.com)

The coupled SWAT–MODSIM (SM) is a tool that can be used in integrated watershed modeling considering both demand and supply sides. In the coupled model, water is allocated from the reservoir to different demand sites, which in SWAT are the HRUs or Subbasins. The allocation is based on the schedule derived from MODSIM's water allocation solutions obtained by iterative minimum cost network flow programs.

The software is written in C#, and is a standalone program. It has a full graphical user interface (GUI), two steps (modules), and runs on MS Windows operating systems (Figure A.1).

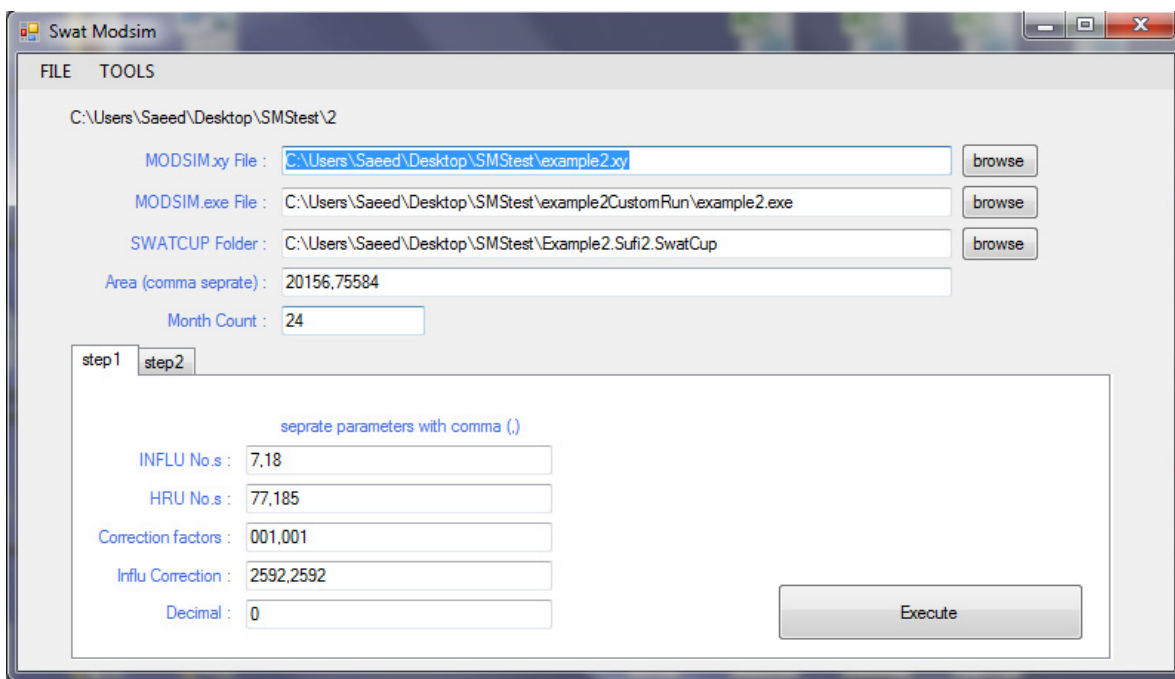


Figure A.1. CCT Graphical User Interface (GUI).

Complete execution of the coupled SWAT–MODSIM model needs the values of state variables to be transferred from the SWAT to MODSIM, and then back from the MODSIM to SWAT (Figure A.2). The following state variables are transferred between the two models:

- Inflow to the reservoirs (from SWAT to MODSIM)
- Net irrigation requirements of agricultural lands (which can be expressed as the difference between Potential (PET) and Actual (AET) Evapotranspiration, Deficit = PET-AET) (from SWAT to MODSIM)
- Water allocated to the demands nodes (HRUs or Subbasins) (from MODSIM to SWAT)
- Source of irrigation (from MODSIM to SWAT)

To consider uncertainties, the SWAT-CUP project of the watershed needs to be built and the M95 PPU of the state variables (from 95ppu_No_Obs.txt file of SWAT-CUP) are extracted and transferred to the MODSIM. In the next three sections, the sequence of implementation of the coupled model is presented.

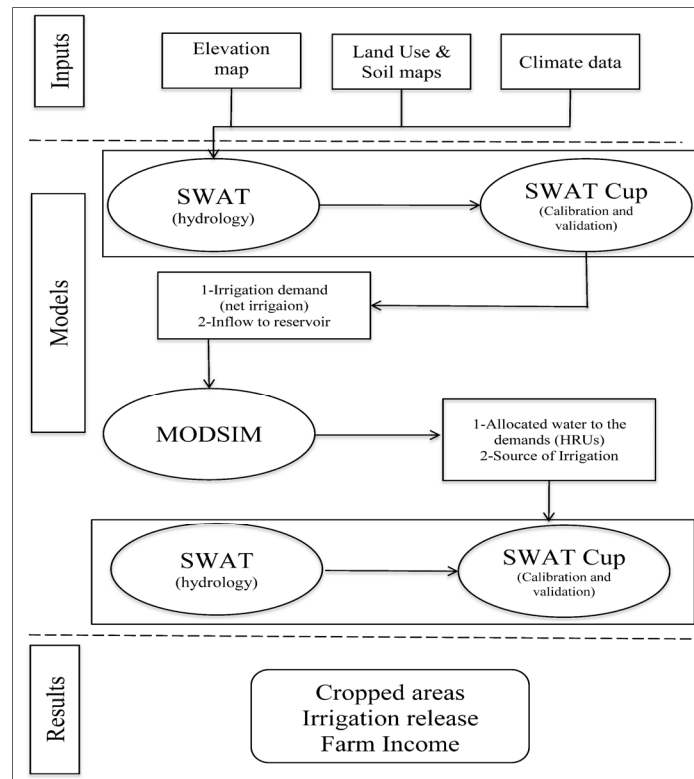


Figure A.2. Overview of the information exchange in the coupled SWAT–MODSIM model ([59]).

S1. Building SWAT and MODSIM Models

Before running the coupled SWAT–MODSIM model, both SWAT and MODSIM models must be built separately to make data exchanging between the models possible. Figure A.3 presents a watershed which has been built with the SWAT model using the Example 1 database provided by SWAT. This SWAT example has 24 subbasins and 239 HRUs. As illustrated in Figure A.3, there are two reservoirs in the watershed in subbasins 7 and 18. The main objective of using the coupled model for this example is to obtain reservoirs' operation in terms of the amount of water supplied to irrigate the winter wheat grown in HRU 77 in Subbasin 9 and HRU 185 in Subbasin 19.

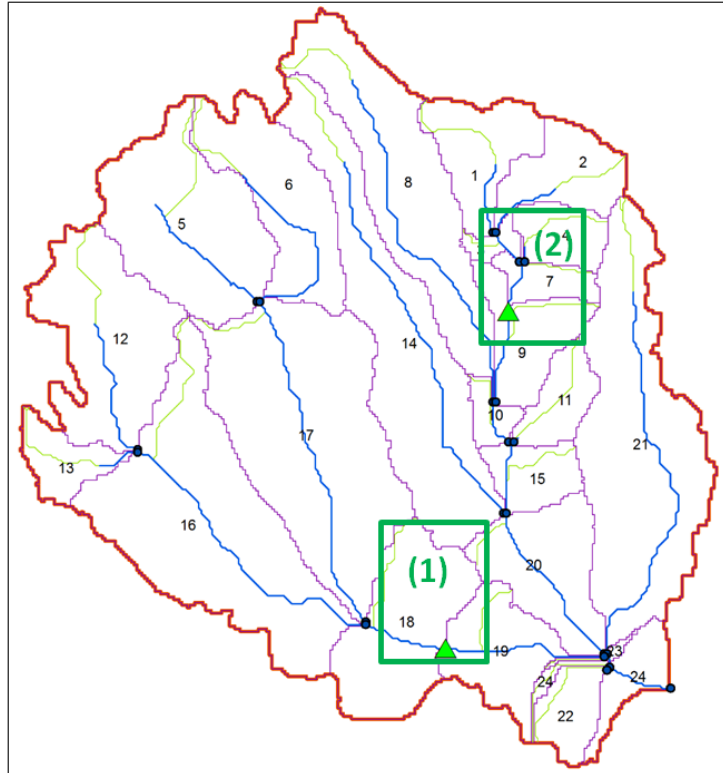


Figure A.3. SWAT model of the example watershed

To build a MODSIM model:

1- All the demand nodes in SWAT must be named as follows:

hru_number or *sub_number*. In this example *hru_77* and *hru_185* (Figure A.4 indicated as (1)).

2- All the reservoirs must be named as follows:

res_number, which are the subbasin numbers where the reservoirs are located. In this example *res_7* and *res_18* (Figure A.4 indicated as (2)).

3- All the non-storage nodes, which are the inflow nodes to the reservoirs must be named as follow:

inf_res_number, which show the subbasin numbers of the reservoirs. In this example *inf_res_7* and *inf_res_18* (Figure A.4 indicated as (3)).

After building both SWAT and MODSIM models, start the SWAT–MODSIM coupled program by executing the **SwatModsim.exe** file to get the main project window.

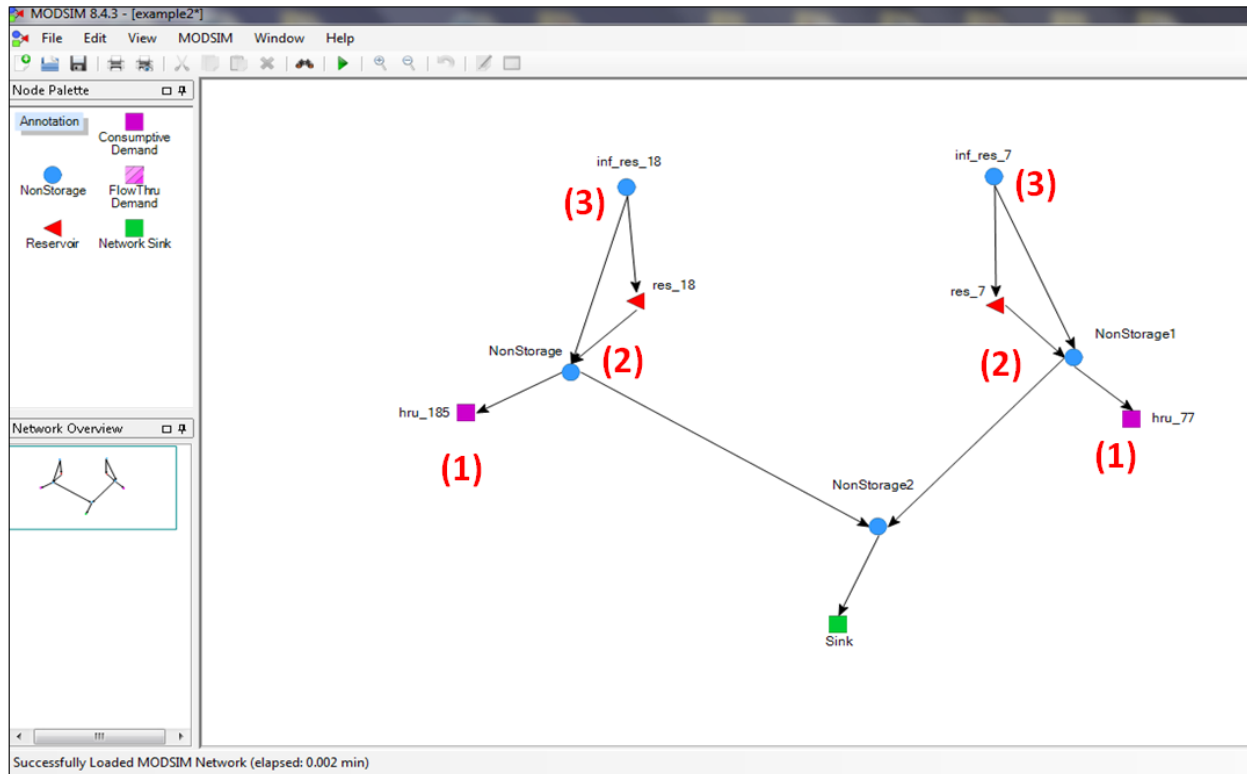


Figure A.4. MODSIM model of the example watershed

S2. General Inputs

We assume that SWAT and MODSIM models have already been built for the study area considering the instruction mentioned in section S.1. At the first step, users create a new project using **FILE** tab at the top left of the window (Figure A.5a). After executing the SM model, users can plot the results using the **TOOLS** tab (Figure A.5b).

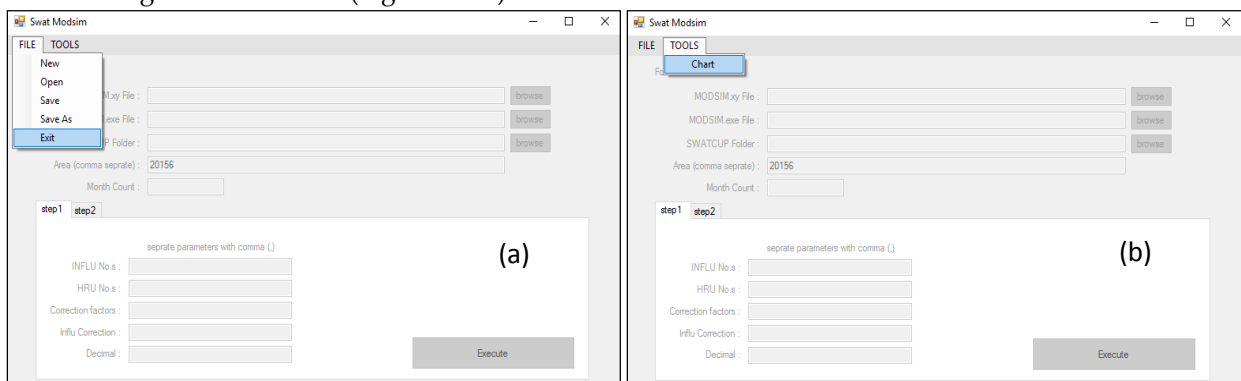


Figure A.5. Coupled (SM) model—(a) FILE, and (b) TOOLS tabs

In general, in the input section of the SM model, users must specify the locations of MODSIM and SWAT-CUP projects (Figure A.6).

Figure A.6. SM model—general inputs

Steps in using this module are:

1- Specify the MODSIM.xy file location (line 2).

2- Specify the MODSIM.exe file location (line 3).

3- Specify the SWAT-CUP project location (line 4).

4-Specify the area (m²) of HRUs which are involved in the SWAT–MODSIM coupled model (this information can be found in “HRULandUseSoilsReport.txt” in ArcSwat project directory in Watershed/text folder) (line 5).

5- Specify the number of time steps (line 6).

All the inputs in the General window are saved in a text file in the SWAT–MODSIM project directory (Figure A.7).

Figure A.7. General inputs of SWAT–MODSIM project

S3. Transferring SWAT Outputs to MODSIM

Click “**step 1**” in the main project menu. This module consists of five parts (Figure A.8). In this window, users specify the HRUs and reservoirs which are involved in the data transferring between the two models.

Swat Modsim

FILE TOOLS

C:\Users\Saeed\Desktop\SMTest\2

MODSIM.xy File: C:\Users\Saeed\Desktop\SMTest\example2.xy browse

MODSIM.exe File: C:\Users\Saeed\Desktop\SMTest\example2CustomRun\example2.exe browse

SWATCUP Folder: C:\Users\Saeed\Desktop\SMTest\Example2.Sufi2.SwatCup browse

Area (comma seprate): 20156,75584

Month Count: 24

step1 step2

seprate parameters with comma (,)

INFLU No.s: 7,18 (1)

HRU No.s: 77,185 (2)

Correction factors: 001,001 (3)

Influ Correction: 2592,2592 (4)

Decimal: 0 (5)

Execute

Figure A.8. SM model—module 1

Steps in using this module are:

- 1- Specify the subbasin numbers of the reservoirs that are planned to allocate water to different demand HRUs or Subbasins (line 1).
- 2- Specify the HRU numbers that are planned to receive water from reservoirs (line 2).
- 3- In the next two lines, specify the correction factors for net irrigation requirements of HRUs and inflow to the reservoirs (lines 3,4). The units of net irrigation requirements (mm) and inflow to reservoirs ($\text{m}^3 \text{s}^{-1}$) in SWAT are different from the time series of demands and inflow to reservoirs ($\text{m}^3 \text{month}^{-1}$). In MODSIM, users need to specify the proper scaling factor for transferring data.
- 4- In the next line, specify the precision of numeric transferred data (line 5).

By pressing **Execute**, the coupled SM model transfers the state variables from the SWAT-CUP project (net irrigation requirements, inflow to reservoirs) to the MODSIM project (MODSIM.xy file). A summary of inputs of module 1 is saved in S1-SWATtoMODSIM-inputs.txt file in the SWAT–MODSIM project directory (Figure A.9).

```

S1-SWATtoMODSIM-inputs.txt - Notepad
File Edit Format View Help

This File contains the data which are need for trasfering SWATCUP outputs to MODSIM

INFLU No.s (comma seprate)
7,18
HRU No.s (comma seprate)
77,185
Correction factors (comma seprate)
001,001
influe Correction factors (comma seprate)
2592,2592
decimal count
0

```

Figure A.9. module 1-inputs of the SWAT–MODSIM project

Also, transferred data to MODSIM are saved into two separate HRUs.txt (Figure A.10) and INFLOW.txt (Figure A.11) files in “OutputModule1” folder in the SWAT–MODSIM project directory.

```

HRU.txt - Notepad
File Edit Format View Help

hru77 395900,664412,1155806,1490371,1998464,2741163,2474748,2752970,1569550,1375271,328400,63597,42446,41126,214363,355539,790527,2126184,2946079,3109929,1623853,152
hru185 1645842,3118022,5069727,6868460,8729910,11449509,11970994,12079342,7664153,6502829,1610733,318737,401864,357883,1132145,1744592,5769127,10105178,13486118,12369

```

Figure A.10. structure of HRUs.txt file

```

INFLO.txt - Notepad
File Edit Format View Help

inf7 382,1378,1796,7148,14424,3535,4061,254,4991,29887,4371,6915,6291,6799,9875,15102,30760,10901,5571,3005,12158,6423,9399,8174,
inf18 77,268,328,1283,2653,592,789,50,907,5409,700,1209,1471,1512,1644,2664,5448,1976,1028,527,2245,1161,1748,1483,

```

Figure A.11. structure of INFLOW.txt file

S4. Transferring back MODSIM Outputs to SWAT

Click “**step 2**” in the main project menu. This module consists of six parts (Figure A.12). In this window, users specify the HRUs and the MGT files which are updated by new irrigation scheduling derived from MODSIM.

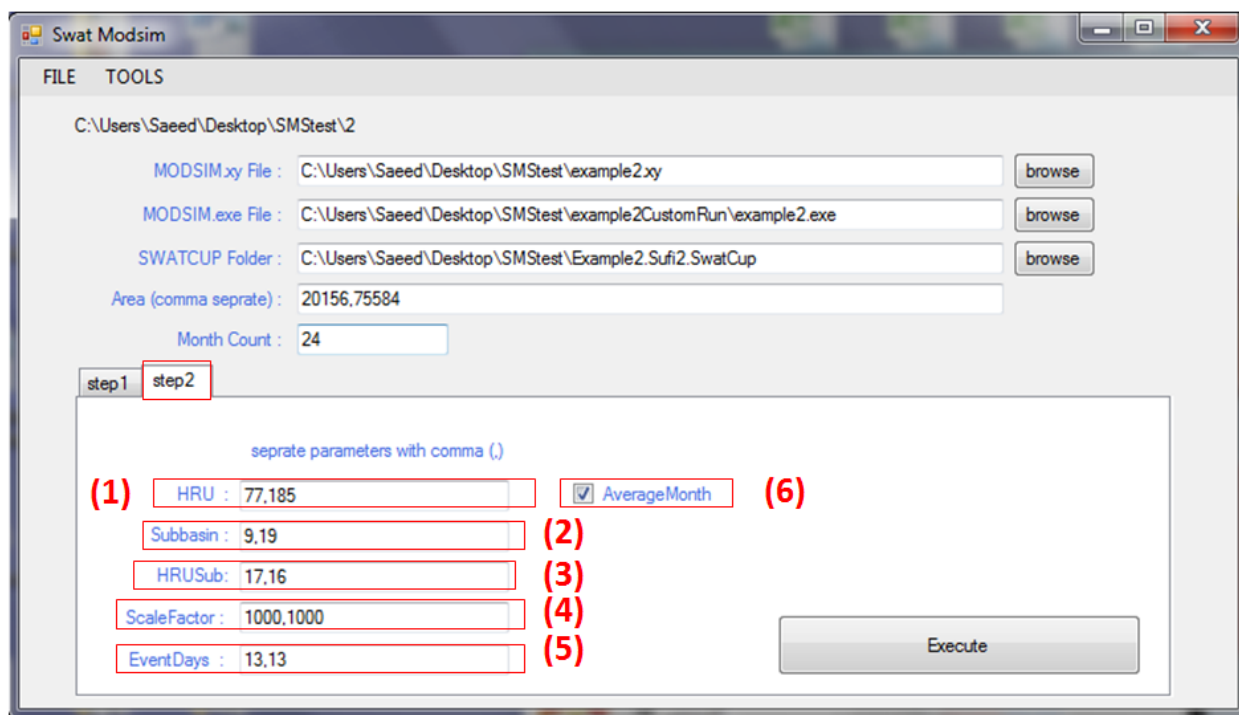


Figure A.12. SWAT–MODSIM model—module 2

Steps in using this module are:

- 1- Specify the HRU numbers that receive water from reservoirs.
- 2- Specify the subbasin numbers where the receiving HRUs are located (e.g., HRU 77 in subbasin 9, and HRU 185 in subbasin 19). Use HRULandUseSoilsReport.txt file in “Watershed/text” folder of SWAT project to fill these lines.
- 3- Specify the HRU number in each subbasin (e.g., in subbasin number 9, HRU 77 is the 17th HRU with mgt file 000090017.mgt, and in subbasin 19, HRU 185 is the 16th HRU with management file 000190016.mgt). Information in lines (2) and (3) is needed to update the MGT files. See the example file 000090017.mgt in Figure A.13.
- 4- Specify the correction factors for irrigation amount which are transferred to SWAT. As it is possible to set different units (i.e. m³, ft³, MCM, etc.) in MODSIM, use the scale factor to transfer them to mm which is the irrigation unit in SWAT.
- 5- Specify the day of each month when water transfer should take place (for irrigation or other uses)
- 6- Specify whether annual rotation of irrigation is applied in MGT files or multi-year rotation is applied.


```

000090017.mgt - Notepad
File Edit Format View Help
|.mgt file Watershed HRU:77 Subbasin:9 HRU:17 Luse:WWHT Soil: LIMERICK Slope: 0-9999 10/23/2015
0 | NMGT:Management code
Initial Plant Growth Parameters
0 | IGRO: Land cover status: 0-none growing; 1-growing
0 | PLANT_ID: Land cover ID number (IGRO = 1)
0.00 | LAI_INIT: Initial leaf are index (IGRO = 1)
0.00 | BIO_INIT: Initial biomass (kg/ha) (IGRO = 1)
0.00 | PHU_PLT: Number of heat units to bring plant to maturity (IGRO = 1)
General Management Parameters
0.20 | BIOMIX: Biological mixing efficiency
81.00 | CN2: Initial SCS CN II value
1.00 | USLE_P: USLE support practice factor
0.00 | BIO_MIN: Minimum biomass for grazing (kg/ha)
0.000 | FILTERW: width of edge of field filter strip (m)
Urban Management Parameters
0 | IURBAN: urban simulation code, 0-none, 1-USGS, 2-buildup/washoff
0 | URBLU: urban land type
Irrigation Management Parameters
2 | IRRSC: irrigation code
1 | IRRNO: irrigation source location
0.000 | FLOWMIN: min in-stream flow for irr diversions (m^3/s)
0.000 | DIVMAX: max irrigation diversion from reach (+mm/-10^4m^3)
0.000 | FLOWFR: : fraction of flow allowed to be pulled for irr
Tile Drain Management Parameters
0.000 | DDRAIN: depth to subsurface tile drain (mm)
0.000 | TDRAIN: time to drain soil to field capacity (hr)
0.000 | GDRAIN: drain tile lag time (hr)
Management Operations:
2 | NROT: number of years of rotation
Operation Schedule:
1 1 2 2 100.00000 0.00 1.00000 0.00 1
2 1 2 2 100.00000 0.00 1.00000 0.00 1
3 1 2 2 100.00000 0.00 1.00000 0.00 1
4 1 2 2 100.00000 0.00 1.00000 0.00 1
5 12 2 2 100.00000 0.00 1.00000 0.00 1
5 30 5 0.00000
10 22 11 1 0.75000 0.00 0.00000 0.00 0.00
10 25 1 28 1800.00000 0.00 0.00000 0.00 0.00
10 30 10 1 2 0.00000 1.00 0.00000 0.00 1
11 1 2 2 100.00000 0.00 1.00000 0.00 1
12 1 2 2 100.00000 0.00 1.00000 0.00 1
17

```

Fig.A13. Management file 000090017.mgt

By pressing **Execute**, the coupled SM model transfers the state variables from the MODSIM project (time series of allocated water to HRU or Subbasins) to the MGT files of the SWAT project. In this step, SM updates the backup folder in the SWAT-CUP project (SM keeps a copy of the original backup folder for further analysis). A summary of the inputs of module 2 is saved in S2-SWATtoMODSIM-inputs.txt file in the SWAT-MODSIM project directory (Figure A.14).

```

S2-SWATtoMODSIM-inputs.txt - Notepad
File Edit Format View Help
This File contains the data which are needed for transferring MODSIM outputs to backup folder of SWATCUP
HRUs
77,185
Subbasin
9,19
HRUSub
17,16
Scales
1000,1000
is Average
True
Event Days
13,13

```

Figure A.14. module 2—inputs of the SWAT-MODSIM project

Also, transferred data from the MODSIM to SWAT-CUP are saved into the IrrAm.txt file (Figure A.15) in the “OutputModule2” folder in the SWAT–MODSIM project directory.

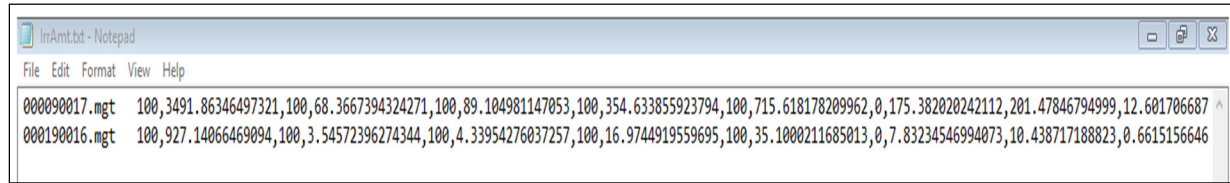


Figure A.15. structure of the IrrAm.txt file

The initial MGT file of HRU 77 in subbasin 9 and updated MGT files are presented in Figures A.16, A.17, A.18.

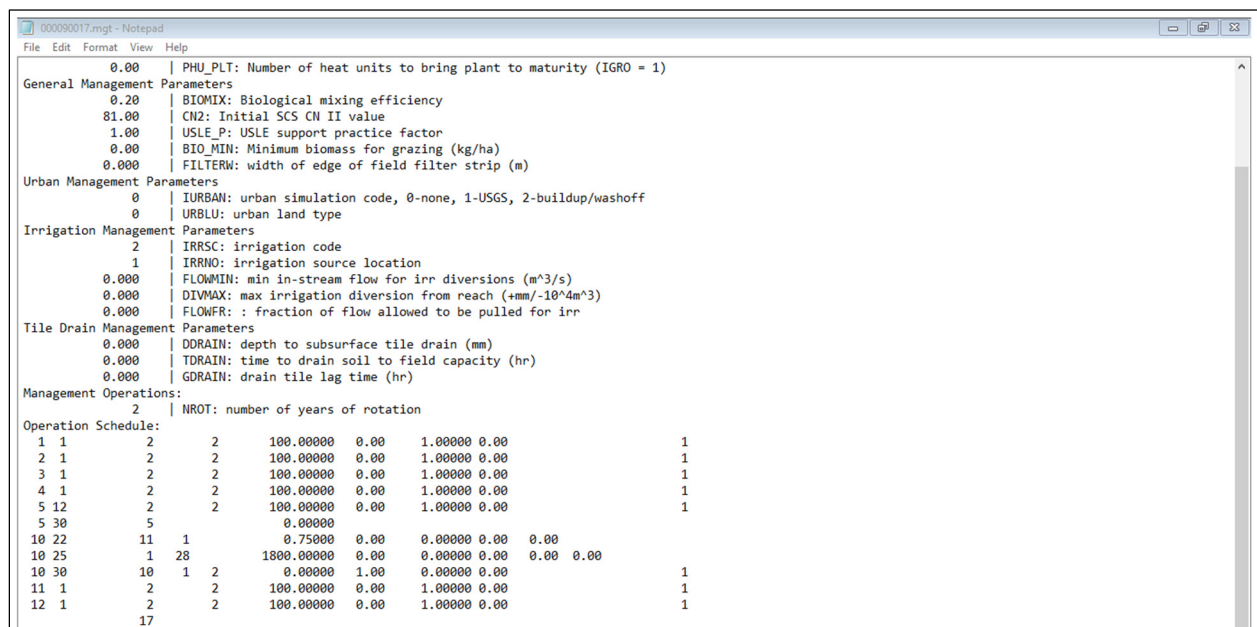


Figure A.16. Initial MGT file of HRU 77.

000090017.mgt - Notepad

File Edit Format View Help

0.000	TDRAIN: time to drain soil to field capacity (hr)								
0.000	GDRAIN: drain tile lag time (hr)								

Management Operations:

2	NROT: number of years of rotation								
---	-----------------------------------	--	--	--	--	--	--	--	--

Operation Schedule:

1	1	2	2	100.00000	0.00	1.00000	0.00		
1	13	2	2	3491.86346	0.00	1.00000	0.00		
2	1	2	2	100.00000	0.00	1.00000	0.00		
2	13	2	2	68.36674	0.00	1.00000	0.00		
3	1	2	2	100.00000	0.00	1.00000	0.00		
3	13	2	2	89.10498	0.00	1.00000	0.00		
4	1	2	2	100.00000	0.00	1.00000	0.00		
4	13	2	2	354.63386	0.00	1.00000	0.00		
5	12	2	2	100.00000	0.00	1.00000	0.00		
5	13	2	2	715.61818	0.00	1.00000	0.00		
5	30	5		0.00000					
6	13	2	2	175.38202	0.00	1.00000	0.00		
7	13	2	2	201.47847	0.00	1.00000	0.00		
8	13	2	2	12.60171	0.00	1.00000	0.00		
9	13	2	2	247.61858	0.00	1.00000	0.00		
10	13	2	2	1482.78428	0.00	1.00000	0.00		
10	22	11	1	0.75000	0.00	0.00000	0.00	0.00	
10	25	1	28	1800.00000	0.00	0.00000	0.00	0.00	0.00
10	30	10	1	0.00000	1.00	0.00000	0.00		
11	1	2	2	100.00000	0.00	1.00000	0.00		
11	13	2	2	216.85850	0.00	1.00000	0.00		
12	1	2	2	100.00000	0.00	1.00000	0.00		
12	13	2	2	343.07402	0.00	1.00000	0.00		
17									
1	13	2	2	312.11550	0.00	1.00000	0.00		
2	13	2	2	337.31891	0.00	1.00000	0.00		
3	13	2	2	489.92856	0.00	1.00000	0.00		
4	13	2	2	749.25580	0.00	1.00000	0.00		
5	13	2	2	1526.09645	0.00	1.00000	0.00		
6	13	2	2	540.83151	0.00	1.00000	0.00		
7	13	2	2	276.39413	0.00	1.00000	0.00		

Figure A.17. Updated MGT file of HRU 77 (two-year rotation)

000090017.mgt - Notepad

File Edit Format View Help

0.000 | FLOWMIN: min in-stream flow for irr diversions (m^3/s)
0.000 | DIVMAX: max irrigation diversion from reach (+mm/-10^4m^3)
0.000 | FLOWFR: : fraction of flow allowed to be pulled for irr

Tile Drain Management Parameters

0.000 | DDRAIN: depth to subsurface tile drain (mm)
0.000 | TDRAIN: time to drain soil to field capacity (hr)
0.000 | GDRAIN: drain tile lag time (hr)

Management Operations:

2 | NROT: number of years of rotation

Operation Schedule:

1 1 2 2 100.00000 0.00 1.00000 0.00
1 13 2 2 1901.98948 0.00 1.00000 0.00
2 1 2 2 100.00000 0.00 1.00000 0.00
2 13 2 2 202.84283 0.00 1.00000 0.00
3 1 2 2 100.00000 0.00 1.00000 0.00
3 13 2 2 289.51677 0.00 1.00000 0.00
4 1 2 2 100.00000 0.00 1.00000 0.00
4 13 2 2 551.94483 0.00 1.00000 0.00
5 12 2 2 100.00000 0.00 1.00000 0.00
5 13 2 2 1120.85731 0.00 1.00000 0.00
5 30 5 0.00000
6 13 2 2 358.10677 0.00 1.00000 0.00
7 13 2 2 238.93630 0.00 1.00000 0.00
8 13 2 2 80.84441 0.00 1.00000 0.00
9 13 2 2 425.40683 0.00 1.00000 0.00
10 13 2 2 900.72435 0.00 1.00000 0.00
10 22 11 1 0.75000 0.00 0.00000 0.00 0.00
10 25 1 28 1800.00000 0.00 0.00000 0.00 0.00 0.00
10 30 10 1 2 0.00000 1.00 0.00000 0.00
11 1 2 2 100.00000 0.00 1.00000 0.00
11 13 2 2 341.58563 0.00 1.00000 0.00
12 1 2 2 100.00000 0.00 1.00000 0.00
12 13 2 2 374.30542 0.00 1.00000 0.00
17

Figure A.18. Updated MGT file of HRU 77 (annual rotation)