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An Automatic Water Assessment Processing System:

To Build the Water Balance Maps of Thailand Basins

Surachai Chantee, Warin Sophonphattanakul, and Prattana Deeprasertkul
Hydro and Agro Informatics Institute,
Ministry of Science and Technology
Bangkok, Thailand.

Abstract— **The water balance is important for planning the agriculture crop production because it can assess the water shortage and the water excess or the water demand of each river basin area. This helps improve efficiency of the current and future watershed management. Soil and Water Assessment or SWAT is a mathematical model which is the method of the water balance assessment. It is reliable and internationally accepted water model. This article introduced the SWAT model to evaluate the water balance of the 25 watersheds in Thailand within one month ago and seven days and six hours in advance. It uses the real rainfall data from the rainfall gauging stations for the backward period and the forecast rainfall data from WRF weather model maps for the forward period. This system is the automatic process as scheduled. The outcomes of this system are the water balance data displayed as the text files and the water balance maps in order that this information are simple to apply for planning the water management.**

Keywords-water balance; SWAT hydrological model; WRF weather model

I. INTRODUCTION

Many areas in Thailand often faced with the effects of drought because of an imbalance in the water supply and the water demand. The consequence is the environmental and social problems such as the lack of water for agriculture, the competition for water consumption of the community, etc. The analysis of the water balance helps to know about the water demand and the water volume in the area that there are adequate or not. It provides assistance and plan for future water use accurately.

The current water balance with SWAT which is a mathematical model is recognized internationally. When apply Weather Research and Forecasting Model or WRF which forecasts the volume of rainfall with high accuracy with SWAT, it can forecast the water balance. This is very useful in planning water management. However, in the SWAT model running, it uses a large volume of data for the processing and the variety of procedures. The factors involved in the process, many factors are changed daily such as rainfall, temperature, moisture in the air, and etc. By limited the number of personnel, it makes the data processing delay and difficult.

The development to assist in the processing model SWAT and to display the map of water balance backward and forward automatically, it helps to assess the water balance easily and quickly. Consequently, the workloads of the personnel in the operation are reduced and the water management can be planed more effectively.

II. BACKGROUND

A. SWAT- Soil and Water Assessment Model

The Soil and Water Assessment Tool (SWAT) [3][4] is the hydrological model developed by USDA Agricultural Research Service (ARS) to study the quantitative impact of watershed management which have the large sizes and complex. SWAT can be evaluated the water balance of the area by using the water balance equation as follow:

$$SW_t = SW_0 + \sum_{i=0}^{n} \left(R_i - Q_i - ET_i - P_i - QR_i\right) \qquad (1)$$

where SW is the Soil Water Content at 15 atmosphere pressure, *t* is the time which is measured in days. *R* is the daily rainfall. *Q* is the daily runoff. *ET* is the daily evapotranspiration. *P* is the daily percolation. *QR* is the daily return flow.

B. WRF-Weather Research and Forecasting Model

The Weather Research and Forecasting (WRF) Model [1] is a mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs. The effort to develop WRF began in the latter part of the 1990's and was a collaborative partnership principally among the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (represented by the National Centers for Environmental Prediction (NCEP) and the (then) Forecast Systems Laboratory (FSL)), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). The WRF model supports a variety of capabilities. These include as follows [5]:

- Real-data and idealized simulations
- Various lateral boundary condition options for real-data and idealized simulations
- Three-dimensional analysis nudging
- Observation nudging
- Regional and global applications
- Digital filter initialization

- etc.

III. TECHNIQUE IMPLEMENTATIONS

The automated systems development of SWAT to calculate the water balance of 25 watersheds is divided into 2 periods shown in Fig. 1 that are as follows:

A. Reanalysis process

Reanalysis process is divided into 2 periods that are the past seven days and the past one month by counting backwards when the system runs such a system to operate on the seventh date, the system will process the data back from the first date to seventh and the eighth date of the last month to the seventh date in this month, respectively.

B. Forecast process

Forecast process includes the projected water balance seven days in advance of the date set for implementation such that the system operates on the seventh date, the system will process the forecast data from the seventh date to thirteenth. The data used to run the SWAT system uses information gathered from the following sources.

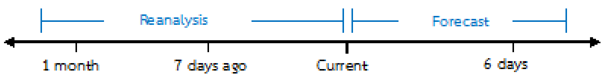


Figure 1. Time periods in SWAT processing system

TABLE I. INPUT DATASETS OF SWAT

Data	Data Sources	Time
Land use	Land Development Department	2009
DEM	Royal Thai Survey Department	1995
Soil group	Land Development Department	2009
Relative humidity	Thai Meteorological Department	Daily
Temperature	Thai Meteorological Department	Daily
Rainfall	Thai Meteorological Department	Daily

For the reanalysis of water balance assessment, the observed data obtain from the field station. The data in Table I are divided into information that is updated infrequently because limitations in the data production such as land use, DEM, and soil group which are the calculated values stored in the model to reduce the processing time. The daily frequency of data collected are imported into the models and calculated the new values every day such as relative humidity, temperature, and rainfall.

The seven days forecast of rainfall data are derived from the WRF model. For the temperature and the relative humidity, the last day data are used to calculate. The method of processing steps as shown in Fig. 2.

Fig. 2 describes the operation of the system. The system begins to pull data from the server of Hydro and Agro Informatics Institute or HAII where stores the input data – the temperature and the relative humidity. Then, these data are

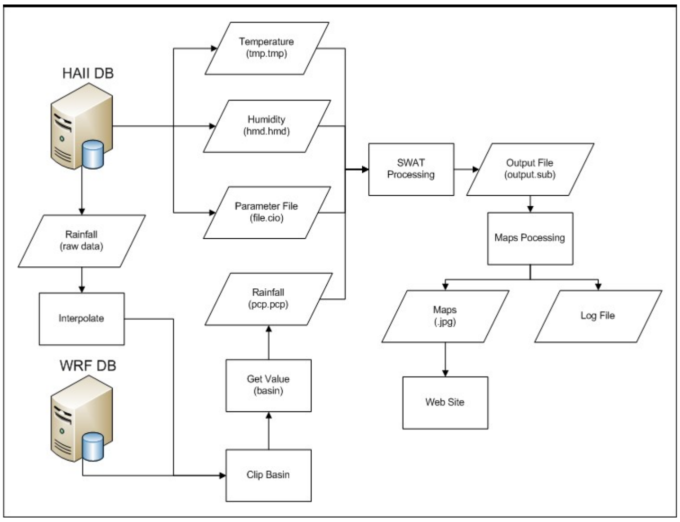


Figure 2. The steps of SWAT processing and creating the map of the water balance in Thailand basin automatically.

arranged into the new input files (tmp.tmp, hmd.hmd, file.cio) by setting into the right format that can be processed in the SWAT model and they are written with Python.

The rainfall data are interpolated and converted into the raster files. Then, the watershed boundaries shape file is applied to crop the required rainfall in each basin boundaries. After that, it calculates the average (mean) of all the pixels in each basin and creates and formats the input file (pcp.pcp) that can import into the SWAT model.

When a preparation of input data has been completed, it runs SWAT software on server and a log file is created to monitor the operation of the system. And then, the SWAT processing is complete, the outcomes of SWAT model - output.sub - are taken to calculate the water balance in the determined period as follows.

The formulas for the water balance in the areas [2]:

$$B_\rho = ((\sum_{d=1}^{\rho} P_d - E_d - W_d) \times A)/1000 \qquad (2)$$

$$PE_\rho = ((\sum_{d=1}^{\rho} PE_d) \times A)/1000 \qquad (3)$$

where B_ρ is the water balance of the area at the determined time such as monthly, seven days period, etc. (MCM^3). P_d is the total amount of precipitation falling on the sub basin during time step (mm H_2O). E_d represents the actual evapotranspiration from the sub-basin during the time step (mm). W_d is the water yield (mm H_2O). A is the area of sub basin (km^2). PE is the potential evapotranspiration the sub-basin during the time step (mm H_2O).

The result values can be taken to be the seven days backward and seven days forecast of water balance criteria as shown in the following table.

Criteria	Detail
balance > 100	More than 100 mm^3
balance > 20 and balance <= 100	More than 20 mm^3 but not over 100 mm^3
|balance| <= PET x 0.3 and balance <= 20	The existing water sufficient to meet demand.
balance < 0 and |balance| >= PET x 0.3 and |balance| <= PET x 0.5	The existing water less than and not over the water demand 50%.
balance < 0 and |balance| > PET x 0.5	The existing water more than the water demand 50%.

The one month backward criteria of water balance are shown in the following table.

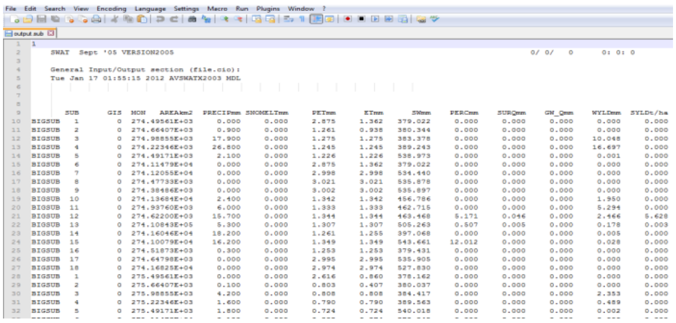
Criteria	Detail
balance > 200	More than 200 mm^3
balance > 40 and balance <= 200	More than 40 mm^3 but not over 200 mm^3
|balance| <= PET x 0.3 and balance < 20	The existing water sufficient to meet demand.
balance < 0 and | balance| >= PET x 0.3 and |balance| <= PET x 0.5	The existing water less than and not over the water demand 50%.
balance < 0 and | balance| > PET x 0.5	The existing water more than the water demand 50%.

Eventually, the water balance maps are created in raster (.jpg) format with Python program on SWAT server and displayed on the website. The system is performed automatically and determined the time schedule by Task Scheduler on SWAT server. The SWAT model starts its processing from 0:15 am each day.

IV. Results

The outputs of SWAT processing system are 2 files as follows:

- *output.sub* is the text file format to display the daily information of water balance in the area. Fig. 3 illustrates the detail of *output.sub* which is the output file of SWAT processing system. Each horizontal line is arranged by Julian date. The last date processed is on a line at the end of file. Each line contains the parameters of each area.



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File  Edit  Search  View  Encoding  Language  Settings  Macro  Run  Plugins  Window  ?
output.sub
1
     SWAT  Sept '05 VERSION2005                                                          0/ 0/    0       0: 0: 0

     General Input/Output section (file.cio):
     Tue Jan 17 01:55:15 2012 AVSWATX2003 MDL



         SUB       GIS  MON    AREAkm2  PRECIPmm SNOMELTmm     PETmm      ETmm      SWmm    PERCmm    SURQmm     GW_Qmm   WYLDmm  SYLDt/ha
BIGSUB    1          0  274.49561E+03    0.000     0.000     2.875     1.362   379.022     0.000     0.000     0.000     0.000     0.000
BIGSUB    2          0  274.66407E+03    0.900     0.000     1.261     0.938   380.344     0.000     0.000     0.000     0.000     0.000
BIGSUB    3          0  274.98855E+03   17.900     0.000     1.275     1.275   383.378     0.000     0.000     0.000    10.048     0.000
BIGSUB    4          0  274.22346E+03   26.800     0.000     1.245     1.245   389.243     0.000     0.000     0.000    16.697     0.000
BIGSUB    5          0  274.49171E+03    2.100     0.000     1.226     1.226   538.973     0.000     0.000     0.000     0.001     0.000
BIGSUB    6          0  274.11479E+04    0.000     0.000     2.875     1.362   379.022     0.000     0.000     0.000     0.000     0.000
BIGSUB    7          0  274.12055E+04    0.000     0.000     2.998     2.998   534.440     0.000     0.000     0.000     0.000     0.000
BIGSUB    8          0  274.47733E+03    0.000     0.000     3.021     3.021   535.878     0.000     0.000     0.000     0.000     0.000
BIGSUB    9          0  274.38486E+03    0.000     0.000     3.002     3.002   535.897     0.000     0.000     0.000     0.000     0.000
BIGSUB   10          0  274.13684E+04    2.400     0.000     1.342     1.342   456.786     0.000     0.000     0.000     1.950     0.000
BIGSUB   11          0  274.93760E+03    6.000     0.000     1.333     1.333   462.715     0.000     0.000     0.000     5.294     0.000
BIGSUB   12          0  274.62200E+03   15.700     0.000     1.344     1.344   463.468     5.171     0.046     0.000     2.466     5.628
BIGSUB   13          0  274.10843E+05    5.300     0.000     1.307     1.307   505.263     0.507     0.005     0.000     0.178     0.003
BIGSUB   14          0  274.16046E+04   18.200     0.000     1.261     1.255   397.068     0.000     0.000     0.000     0.005     0.000
BIGSUB   15          0  274.10079E+04   16.200     0.000     1.349     1.349   543.661    12.012     0.000     0.000     0.028     0.000
BIGSUB   16          0  274.51873E+03    0.300     0.000     1.253     1.253   379.431     0.000     0.000     0.000     0.000     0.000
BIGSUB   17          0  274.64798E+03    0.000     0.000     2.995     2.995   535.905     0.000     0.000     0.000     0.000     0.000
BIGSUB   18          0  274.16825E+04    0.000     0.000     2.974     2.974   527.830     0.000     0.000     0.000     0.000     0.000
BIGSUB    1          0  275.49561E+03    0.000     0.000     2.616     0.860   378.162     0.000     0.000     0.000     0.000     0.000
BIGSUB    2          0  275.66407E+03    0.100     0.000     0.803     0.407   380.037     0.000     0.000     0.000     0.000     0.000
BIGSUB    3          0  275.98855E+03    4.200     0.000     0.808     0.808   384.417     0.000     0.000     0.000     2.353     0.000
BIGSUB    4          0  275.22346E+03    1.600     0.000     0.790     0.790   389.563     0.000     0.000     0.000     0.489     0.000
BIGSUB    5          0  275.49171E+03    1.800     0.000     0.724     0.724   540.018     0.000     0.000     0.000     0.002     0.000
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Figure 3. The output file of SWAT processing system (output.sub).

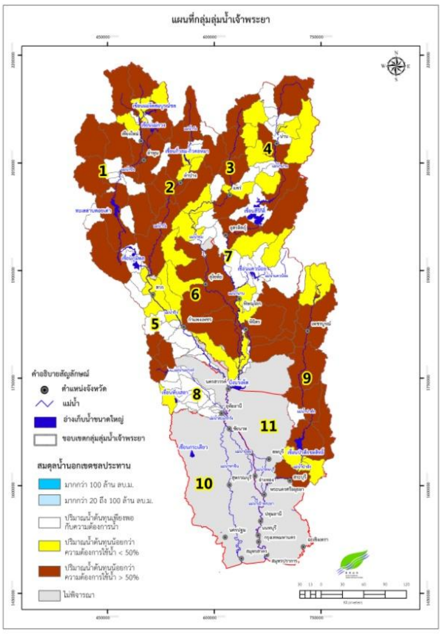

Figure 4. The sample of water balance map in the Chao Phraya river basin.

- The map displaying the water balance forward / backward of basin and watershed groups is the image file. The system creates the map in jpeg file format to display the water balance follow the determined criteria in different colors. The outside areas of the model are shown in gray as illustrated in Fig. 4.
  - The monthly water balance map is determined to produce every the first Wednesday of the month.
  - The seven days backward water balance map is determined to produce on Monday and Thursday of every week.
  - The seven days forecast water balance map is determined to produce on Monday and Thursday of every week.

All outputs are stored on SWAT server, then show up it on website.

V. Conclusions and Discussions

The automatic SWAT processing and mapping system of water balance assists in the quick assessment of water balance backward and forward, according to the scheduled time, and every river basin and watershed group as programmed. In addition, the system helps reduce the workload of the staff in the process operation. Even if our WRF model produced 75% accurate precipitation, but there is still the projected information limitation of some factors that is using the last information instead of the forecast information such as temperature, humidity, etc. It may make the results to be less accuracy. Moreover, there is the limitation of database which the dataset still be imported by staff. Therefore, it causes the uncertain time to import, if some events unexpected happen such as the employees forget import the data and the data are not imported the system because of the long holidays. It makes lack some information in some periods. Then, some errors may occur when the SWAT processing system run.

For the system development in the future, in order to the results are more accurate, we will study and find out the other forecast data such as temperature, humidity, and etc. to replace the use of the latest data. In addition, the better design and implementation of the data in the database reduces the errors of the missing data. Moreover, the system should have the accuracy verification of predictions with actual events and adjust processing techniques to more quickly operation.

REFERENCES

[1] Michalakes, J.G., M. McAtee, J. Wegiel, "Software Infrastructure for the Weather Research and Forecast Model", in proceedings of UGC 2002, June, Austin, Texas, 13pp.

[2] Nipon Thangtham, Piyapong Tongdeenok, Wisutthiphun Mahaascha, Venus Tuankrua, and Nuttapon Chaiyawannakarn. "Public Domain Model (SWAT/GIS) Development on The Chao Phraya River Basin." , Retrieved April 1st, 2013, http://www.maewang.net/maewang/maewang/game_report/บทที่%204.pdf, 2002.

[3] Neitsch, S.L., Arnold, J.G., Kiniry, J.R., Srinivasan,R., Williams,J.R. version 2005. "Soil and Water Assessment Tool Theoretical Documentation.", January 2005.

[4] Neitsch, S.L., Arnold, J.G., Kiniry, J.R., Srinivasan,R., Williams,J.R. version 2005. "Soil and Water Assessment Tool Input/Output File Documentation.", September 2004.

[5] The National Center for Atmospheric Research (NCAR), the University Corporation for Atmospheric Research (UCAR), "wrf-model.org: User Guide V.3" 2012.