Forecasting Crop Irrigation Water Requirements

Reclamation Science and Technology Program

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1. Introduction

A conglomeration of tools (hereafter referred to as ET (evapotranspiration) Demands Model[1] or Demands Model) have been developed over a period of years for estimating crop irrigation water requirements (CIR) and are currently being used to support the Reclamation West-Wide Climate Risk Assessment (WWCRA) agricultural water demand estimation as well as projects under the Reclamation Basin Study Program.

These tools are a combination of Microsoft Excel® and programs that have evolved into versions written in Visual Basic for Applications (VBA; e.g., Allen and Robison 2009[2]) and subsequently the VB.net framework. There is a need to have a version of the Demands Model program coded in a language that is platform-independent, i.e., may be executed on Windows, Macintosh, and Linux/Unix machines.

The objective of this research project was to develop a computing framework to forecast crop irrigation water requirements (CIR) from daily to seasonal time scales. In addition to supporting the Reclamation Basin Study Program, there is a need for forecasting CIR for Reclamation Projects. To that end, the Klamath Project is an example where CIR forecasting system is being developed to support water management in the Basin, and will be run on a real-time mode. Furthermore, Reclamation Technical Service Center (TSC) staff is in consultation with the Albuquerque Area Office (AAO) staff to explore the possibility of porting the ET calculation portion of the existing ET Toolbox[3] system to the computing framework described in this Report.

2. Methodology

The methodology consists broadly of two main tasks: (1) review of available forecast data resources; and (2) apply ET demands model to generate CIR forecasts and develop the forecast archive. Each of these main tasks has one or more subtasks under them.

2.1 Review of Available Forecast Data Resources

The ET demands model requires as its meteorological inputs – precipitation, minimum and maximum temperature, and wind speed. Additional variables required to run the model such as solar radiation and relative humidity are estimated using well established empirical relationships such as Thornton and Running (1999)[4].

[1] The focus here is agricultural water demand and does not include municipal, industrial and other water demands. Furthermore, the agricultural water demand specifically refers to crop irrigation water requirements, and does not include any losses through agricultural water delivery infrastructure.
[2] Allen, R.G. and C.W. Robison. 2009. "Evapotranspiration and Consumptive Irrigation Water Requirements for Idaho," University of Idaho Report, 222 pp. Available at http://www.kimberly.uidaho.edu/ETIdaho/.
[3] Brower, A. 2008. "ET Toolbox - Evapotranspiration Toolbox for the Middle Rio Grande: A Water Resources Decision Support Tool," 159 pp. Available at http://www.usbr.gov/pmts/rivers/awards/ettoolbox.pdf.
[4] Thornton, P.E. and S.W. Running. 1999. "An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation," Agricultural and Forest Meteorology 93:211-228.

Developing forecast products from daily to seasonal timescales is contingent on available independent variable information prior to the forecast period. For example, if sea surface temperature (SST) is an independent variable (input) to the seasonal CIR forecast model, current month's SST will be necessary to make a forecast for the upcoming month.

For example to develop short term (1-7 day) forecast for the Klamath Basin, bias corrected CNRFC (California-Nevada River Forecast Center) forecast data will be used as input to the Demands Model.

In addition the ET demands model requires information on crop type distribution, soil properties, and coefficients (crop curves) related to crop growth and harvest.

2.2 ET Demands Model

2.2.1 Development of the ET demands model for use in CIR forecasting

Prior to any application of the ET demands model to develop forecasts, the first step in the process was to develop a platform independent version of the ET demands model from the available version of the software developed using VBA, VB.net and MS Excel (collectively referred to as the Microsoft® or MS application). For this purpose, Python[5] was chosen as the target language due to its portability (available on almost every platform), relative ease of use and maintenance, and widespread use and acceptance in the scientific community as an open-source programming language.

A review of the current MS application reveals several improvements that were considered while porting to the Python language. These include:

- elimination of global variables
- simplification of code structure where possible and dividing functionality into logical units
- organizing data into logical structures including revision of input data file structure and formats

The primary goal was to develop a portable and maintainable version that performs the data handling and calculations involved in estimating ET demands (CIR) for forecasting and other application needs in Reclamation.

Elimination of global variables

Global variables from the MS application were eliminated in Python by creating a class that contains those that can't be easily eliminated. The 'container' class currently has about90 variables. Once instantiated, this object is passed around the Python version of the code.

[5] Python Software Foundation, https://www.python.org/.

Simplification of code structure and dividing functionality into logical units

The ET demands model has two sub-models[6]. One to calculate reference evapotranspiration (REFET) and a second model to estimate crop ET (CROPET).

The Python version of the REFET module is very similar, and almost a direct translation of the MS application. The only change was to routines used to read data were moved outside of the REFET module. This was possible because, the MS application had minimal global variables and consisted of 32 functions that could be directly translated into Python methods.

The CROPET model is more complex. This module in the MS application is one large file with nearly 250 global variables and 28 functions. The translation strategy was to organize the 28 functions into themes and divide into separate files. This resulted into 17 Python files containing the 28 functions from the original code. Global variables from the MS application that cannot be easily eliminated were passed using the container class that held the global variables (about 90) to the 17 files containing the Python methods. Furthermore, the MS application relied on scalar and array variables to hold input data in memory. Data structures, classes and Python dictionaries were designed based on themes to logically hold input data in memory. Significant classes include:

- InitCropCycle - Container class for VB global variables (no global variables in python version).
- CropParameters - Instantiated for each crop, contains crop specific information.
- CropCoefficients - Instantiated for each crop coefficient curve, contains all curve data and has methods to do lookups and query values.
- ETCell - Instantiated for each ET cell (spatial unit used for ET estimation), contains cell attributes such as soil properties and meteorological data.

Organizing data into logical structures including revision of input data file structure and formats

Suggested improvement to input data file structure include making existing text files smaller and organized in a logical directory structure. Alternatively use of the Hierarchical Data Format version 5 (HDF5)[7] data storage model is suggested as this format offers flexibility and the data is stored (referenced) in a directory type structure providing a logical extension of the text file directory structure. Furthermore, the HDF5 data model has the notion of attributes, and would be an easy way to share with others and provide interface to users through for example Microsoft Excel. A conceptual layout of the data interface is shown in Figure 1.

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[6] For theoretical details on estimating ET the reader is referred to, Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. "Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements," Irrigation and Drainage Paper 56, Food and Agriculture Organization of the United Nations, Rome, 300 pp.

[7] URL, http://www.hdfgroup.org/HDF5/doc/UG/03_DataModel.html.

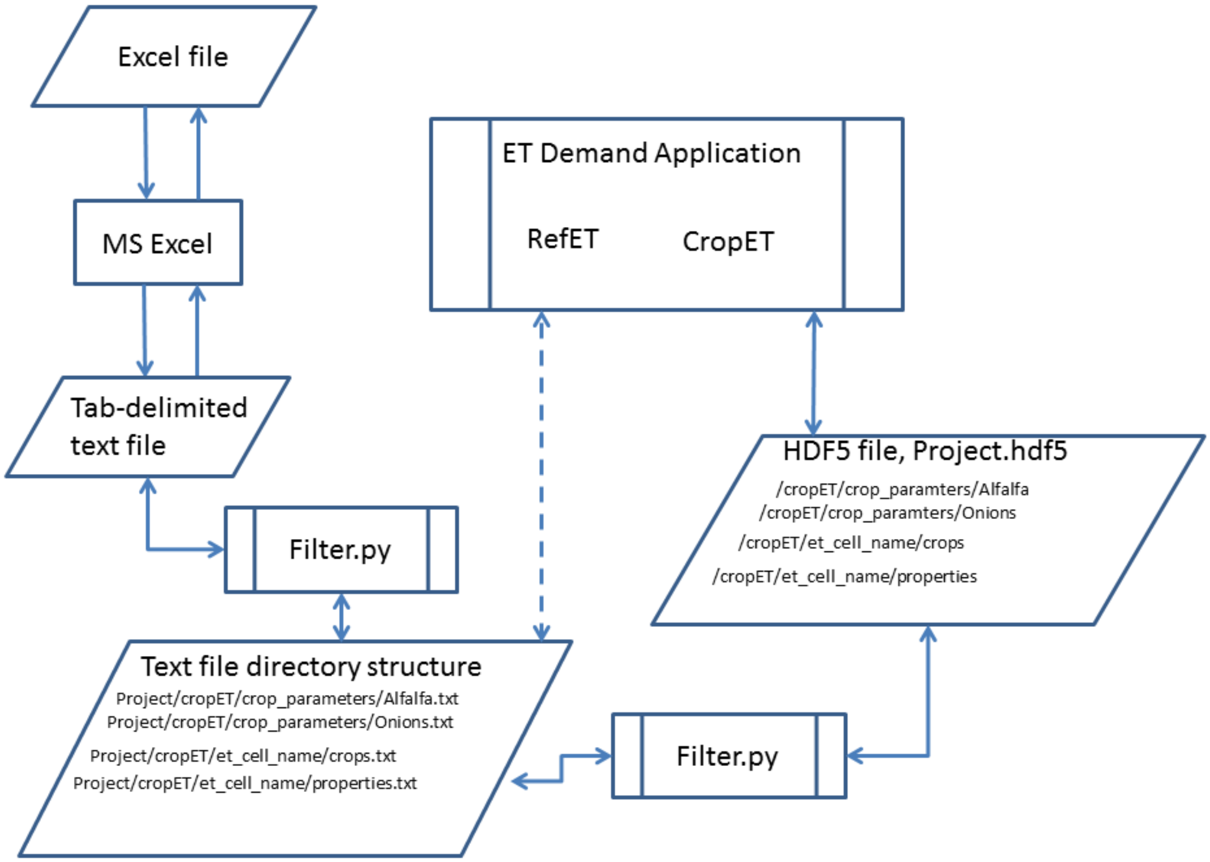

Figure 1. Data formats to interface with the ET Demands model.

2.2.2 Calibration of the ET demands model

The ET demands model based on the MS application has been calibrated for all the eight major Reclamation river basin as part of the WWCRA effort. A report describing the model calibration will be published in the near term by Reclamation.

2.2.3 Application of the ET demands model

The Klamath Basin will be the first project where we intend to apply the Python version of the ET demands model using the available calibration for crops in the Klamath Basin.

To date we have developed the approach that will be used to develop the meteorological inputs to forecast CIR for the Klamath Basin using the CNRFC forecasts. Moving forward we intend to apply these inputs in the calibrated CIR model to generate CIR forecasts in real-time.

3. Summary

As part of this project we have developed an approach to forecast CIR and guide agricultural water needs for Reclamation Projects and for Reclamation planning needs. This project supported the research need to conceptualize the ET demands model so that it can be adapted to forecasting applications including research on data resources for CIR forecasting. Developing the Python version of the demands model was supported by funding from the WWCRA program and the Klamath Basin Area Office (KBAO).

The intent is to apply the newly developed Python version of the demands model in an application to the Klamath River Basin and subsequently explore substitution of the components in the ET Toolbox application of the Middle Rio Grande in collaboration with AAO.

For the Klamath Basin, the process to generate short-term (1-7 day) forecasts of the meteorological variables needed by the CIR model has been developed. Next, we would like to use the historical archive of these short term forecasts and use it in the demands model to verify historical CIR forecasts. We plan to continue to work with KBAO to develop real-time CIR forecasts both on a daily basis and also at seasonal time scale as an experimental forecast product starting in water year 2015.