TECHNISCHE UNIVERSITÄT DRESDEN

Version 1.0

DEFICIT IRRIGATION TOOLBOX (DIT)

Quick Start Guide

5 April 2019

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Content

1.   Introduction

Welcome to **Deficit Irrigation Toolbox (DIT)**. The open-source software to simulate crop-water productivity in MATLAB language. The toolbox allows you to perform the complex analysis of crop yield response to climate change, soil variability, and water management practices. It includes several crop models and various irrigation strategies which allow you to make a comprehensive assessment of crop yields in variable environments.

This guide will help you to get familiar with basic DIT functionality, so you would be able to start your own simulations. More experienced DIT users can skip it go directly to the complete user guide *Instructions/UserGuide.pdf* or download it from the official website: http://bit.ly/TUD-DIT

If you have any problems with running the code, please don't hesitate to contact us by writing an email to hydrologie@tu-dresden.de with subject: "[DIT] Help request".

Yours faithfully,

DIT team

## 2.	How to start?

To make your first steps, you need to have a DIT copy. To get it, please follow the download procedure on the official website: http://bit.ly/TUD-DIT. Additionally, you need to have MATLAB version 2017a or newer, which you can get at https://www.mathworks.com. Once you have DIT and MATLAB, we are ready to start.

First, let's have a look at the DIT folder. It consists of 4 subfolders and the main script DIT.m:

- **Add-ins** - additional tools that we've created in the process of DIT development: Converter from AquaCrop to AquaCrop-OS (AOS) and Converter of the climatic database into DIT format;
- **Instructions** - here you can find the complete user guide and other related literature;
- **Projects** - here the inputs, configurations, and results of your projects are stored;
- **Scripts** - storage of all DIT scripts;
- **DIT.m** - script to run the simulation(s).

As you can see, there are some Examples in */Projects* that we can use. Copy the first example *Example1_No_Irrigation* into */Projects* and open it. There should be 2 subfolders and configuration file:

- **Data** - location of input files;
- **Results** - here the outputs will be saved;
- **Example1_Config.m** - configurations of your project.

This example uses a simple Soil-Water Balance Model (SWB) (Rao et al. 1988) that needs only a few inputs and gives you the yields as a ratio of AET to PET in %. The location of input data is a small arid region in the eastern seaside of Oman.

Now you are ready to go to the next chapter and run your first DIT simulation.

3.   My first simulation with DIT - No Irrigation

It is time to do some crop modeling. You already have a project */Projects/Example1_ No_Irrigation* and now you only need to set up the main script DIT.m (find it in the root folder):

- Open *DIT.m*;
- Provide the path of your DIT to *DIT_path* variable or leave as '' if it is the current MATLAB folder;
- Provide the path of your configuration file to *config_path* variable. In our case: 'Projects/Example1_No_Irrigation/Example1_Config.m';
- Click Run button.

Fantastic! You see some colorful graphs and outputs in Command Window. Moreover, those results are now available in */Projects/Example1_No_Irrigation/Results*. Go there and open the seasonal report (txt file). As you can see, there are only a few non-zero yield seasons due to the high level of evaporation (ET). How can we make it better? By applying irrigation of course. You can find examples of several irrigation strategies in the next Sections. Good luck.

Extra: You can open your configuration file */Projects/Example1_No_Irrigation/ Example1_Config.m* and play with some parameters. For example, try to change the initial soil moisture *conf.SWB.theta0* to the same value as *conf.SWB.fc*.

4.   Examples of simulations

4.1. Full Irrigation / Full Irrigation with thresholds

This strategy has unlimited water storage. Therefore, we use it to understand what are the highest crop yields we can harvest. Let's check it out using our previous example from Oman. Follow the next steps:

- Copy the second example *Example2_Full_Irrigation* into */Projects*;
- Set up *DIT.m* in the same way as in Section 3 but for our current project;
- Click Run button.

As you can see, now we reached 100% crop yields. On the other hand, look at the amount of water we used - 930 mm. It happens because, under this strategy, DIT irrigates whenever the water content is less than 90% which can occur almost every day under Omani climatic conditions.

Fortunately, we can change it. Open the configuration file */Projects/Example2_Full_Irrigation/ Example2_Config.m* and switch *conf.irr.strategy* to 3. Now we can change *conf.irr. fc_threshold* and *conf.irr.irr_threshold* to improve our irrigation management. Run DIT again and analyze the results.

4.2. Constant Irrigation / Crop-Water Production Function

This strategy has limited water storage and irrigation events are equally distributed throughout the growing season. Let's see how it works by following the same procedure as before:

- Copy the third example *Example3_Constant_Irrigation* into */Projects*;
- Set up *DIT.m* in the same way as in Section 3 but for our current project;
- Click Run button.

As you can see, the irrigation storage is 200mm which is not enough to have high crop yields. So let's change *conf.irr.storage* to 400mm in the configuration file *Projects/Example3_ Constant_Irrigation/Example3_Config.m*. Moreover, you can play with *conf.irr.step* to see which irrigation time step will give the best results.

Extra: Usually, we need to check several values for our irrigation storage. When you run them together, DIT presents the results as a **Crop-Water Production Function (CWPF)**. You can do it by setting *conf.irr.storage* as an array, e.g. [0 200 400 600].

4.3. Decision Table

This is our first optimization strategy. On a daily basis, the algorithm measures the available water in your soil and irrigation storage. Then, it defines how much water to irrigate according to fractions

of full irrigation. To do it, Decision Table uses daily soil moisture data and 6 decision variables - 2 thresholds and 4 fractions of full irrigation:

- Field Capacity threshold defines wet and dry soil;
- Available water storage threshold defines few and much water;
- Fraction for wet soil and few water;
- Fraction for dry soil and few water;
- Fraction for wet soil and much water;
- Fraction for dry soil and much water.

Those 6 decision variables are optimized by CMA-ES optimization algorithms by Hansen et al. (2003) according to the selected objective function. Note that this process is time-consuming. Therefore, we recommend limiting the number of generations *conf.irr.optmz_end*.

Let's run this example by following the next steps:

- Copy the fourth example *Example4_Decision_Table* into */Projects*;
- Set up *DIT.m* in the same way as in Section 3 but for our current project;
- Set *conf.irr.optmz_end* in the configuration file to some lower value, e.g. 20;
- Click Run button.

As you can see, the irrigation storage is the same as it was for the constant irrigation but the yields are much higher. Now, try to use CWPF and compare the results to the ones from the constant irrigation run.

4.4. GET-OPTIS

GET_OPTIS optimizes the irrigation schedule using evolutionary algorithms created by Schütze et al. (2012). As a result, it distributes irrigation events throughout the growing season in the way that produces the highest crop yields according to the selected objective function.

To proceed, follow the next steps:

- Copy the last example *Example5_GETOPTIS* into */Projects*;
- Set up *DIT.m* in the same way as in Section 3 but for our current project;
- Click Run button.

As you can notice, this algorithm works faster than Decision Table but the results are usually very similar. Moreover, GET-OPTIS is easier to implement in the real field because it produces a single irrigation schedule for the whole growing season and doesn't need soil moisture measurements.

5.   Next steps

Congratulations, you have just finished **Quick Start Guide**! Now you are familiar with basic DIT functionality and ready to start your own simulations.

We recommend you to copy and use the DIT project template which you can find in */Projects/ProjectTemplate* instead of working with mentioned above examples. This template has a complete configuration file with all possible options for your simulations. Moreover, in */Projects/ProjectTemplate/Data* folder, you can find examples of input files for all crop models.

More instructions you can find in comments to the code lines or in the complete user guide */Instructions/UserGuide.pdf*.

If you have any further questions or recommendations, please contact us by one of the options provided on our website.

References

1. Rao, N.H., Sarma, P.B.S., Chander Subhash: A simple dated water-production function for use in irrigated agriculture, Agricultural Water Management, Vol. 13, S. 25-32, 1988 DOI: 10.1016/0378-3774(88)90130-8

2. Hansen, N., Müller, S. D., Koumoutsakos, P.: Reducing the time complexity of the derandomized evolution strategy with covariance matrix adaptation (CMA-ES). Journal of Evolutionary computation, Vol. 11, P. 1-18, 2003. DOI: 10.1162/106365603321828970

3. Schütze, N., Paly, M. & Shamir, U.: Novel Simulation-based algorithms for optimal open-loop and closed-loop scheduling of deficit irrigation systems. Journal of Hydroinformatics, Vol. 14.1, P. 136-151, 2012. DOI: 10.2166/hydro.2011.073