WYSPAC: A Water-Yield Simulation for Perennial and Annual Crops

by

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This program was designed to fulfill the requirements and obligations of contract VAN85-2249A.

files (roger)
d.paran
d.weather
(specific to f77) wyspw.f (object file) → a.out
output file: d.result

I wish to thank the people at the Inland Waters Directorate, Pacific & Yukon Region, for making my short stay there an enjoyable one.

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Introduction to WYSPAC

The following report descibes WYSPAC[1], a program for simulating the water-yield relationships of various crops under different soil and irrigation conditions.

The methods employed in formulating this program are substantially those used in an earlier study by Wigington and Short[2]. The user is referred to the above study for a detailed account of the simulation procedure. Essentially the simulation of a water-yield response for any particular crop involves determining an effective range of soil moisture levels over which stress is thought to occur, the degree of stress as it effects yield within that range, and relating this to the specific time or phase of the crop's growing season. These two water stress factors, degree and timing, are crop specific in that different crops react differently to soil water levels at different phases of their growing cycles. By calculating the amount of water available to the crop in the soil for each day of the growing season, the two water stress factors can be determined. The sum of these daily water stress amounts divided by the days per growing season provides

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[1]Water Yield Simulation for Perennial and Annual Crops.
[2]Ian Wigington and Cameron Short, "The Effects of Water Restrictions on Apple Orchard Profitability in British Columbia's Okanagan Valley", report prepared for the Inland Waters Directorate, Pacific and Yukon Region, June 1985.

an estimate of the yield reduction for the year.

In order to encompass a wide range of crop types, the WYSPAC program is designed to allow considerable user flexibility in selecting the parameters which determine the simulation environment. The WYSPAC User Guide which follows this section provides a detailed explanation of each parameter selection. The remainder of this section discusses some of the reasoning behind the WYSPAC parameter selection method. Numbers in brackets correspond to parameter type numbers in the User Guide.

The 18 parameters through which the user is able to control the simulation can be divided into 4 general areas: crop choice, soil type, growing season, and irrigation.

1. Crop choice

The user can choose from 7 crops (1): tree fruits, grapes, alfalfa, wheat, corn, potatoes, and sugar beets. The choice of a particular crop determines the characteristics of the degree and timing of water stress factors as well as a specific set of evapotranspiration coefficients[3]. The crop type also

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[3] see Hargreaves, 1968.

determines the rooting depth, a factor important in determining the total volume of soil water available to the crop.

Other parameters are also related to crop choice. The expected life span (in years) of the crop (3) indicates whether the crop is annual or perennial. The year when a perennial crop is expected to reach maturity (4) determines whether growth or yield reduction calculations should be performed in any given year of the perennial crop life. The type of crop would also play a role in determining the initial soil water level (8) at the start of the growing season. For example, the assumption of a wet soil at the start of the growing season would be acceptable for tree fruits, whereas for corn the soil would have to be be assummed dry enough to facilitate planting.

2. Soil type

The choice of one of 4 soil (2) types (sandy, sandy loam, silt-loam, or organic), together with the crop rooting depth, determines the maximum amount of water the soil can hold, the field capacity. The field capacity of the soil over the effective rooting depth, together with the soil moisture level on any given day of the growing season, determines the degree of water

stress for that day.

3. Growing season

Both the crop type and the location for which the simulation is desired determine the period to be defined as the growing season. By allowing the user to choose the starting point (5) and ending point (6) of the growing season (to the nearest month), a variety of growing locations can be accommodated.

4. Irrigation

Because different crops can be irrigated using a variety of irrigation systems and methods, several parameters are used to specify the irrigation component of the simulation.

Three types of irrigation patterns (9) are available: rotation, periodic, and sufficient. Rotation irrigation, suitable for such crops as tree fruits and grapes, requires the user to specify the number of rotation sets (12) needed to irrigate the entire planted area, the starting (15) and ending (16) days of the irrigation period within the growing season, and the amount of water applied per irrigation (13). Each rotation is assummed to encompass 1 day, thus for a system of 16 12 hour rotation sets, the

rotation number entered by the user would be 8.

Periodic type irrigation allows the user to specify up to 5 irrigation times (11) during the growing season as well as the amount (constant) of each irrigation (13). Such an irrigation regime is perhaps suitable for field crops such as corn, wheat, and alfalfa.

The third type of irrigation, termed sufficient, provides irrigation in amounts so as not to allow the crop to undergo any water stress at any time during the growing season. This irrigation type is suitable for determining a minimum no-stress irrigation level for any crop. As a sufficient amount of irrigation is automatically provided to the crop, no irrigation amount need be designated by the user.

One other irrigation parameter which affects crop irrigation in rotation and periodic irrigation choices is the irrigation application efficiency factor (14). The program user guide which follows provides a table of irrigation systems and their corresponding water application efficiencies.

- All files under Roger
- put on floppy when possible.

A Users Guide to WYSPAC

Introduction

The purpose of WYSPAC[4] is to provide a simple means of estimating the impact which different levels of irrigation would have on crop yields. WYSPAC uses a system of variable input parameters to facilitate water-yield estimations for a variety of annual and perennial crops. WYSPAC also makes use of historical weather data to simulate atmospheric water demand for a particular area.

The following pages of this manual explain the data requirements of a WYSPAC estimation and how such data should be read into the model. An interpretation of the WYSPAC output is also given.

Weather Data

WYSPAC requires daily observations on temperature and rainfall for the particular area for which an estimation is required. Weather data must be of the specific format of the data available on tape from the Atmospheric Environment Service.[5] The specific records WYSPAC requires are:

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[4]Water-Yield Simulation for Perennial and Annual Crops

[5] weather data can be obtained through written request to: Atmosheric Environment Service, Canadian Climate Centre, Data Management Division, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

Monthly Record of Daily Values for
Total Precipitation (element 012)
Daily Maximum Temperature (element 001).

Since WYSPAC randomly selects 'weather years' from the weather data read in, the greater the number of years of data available, the more general the results of the simulation.

All weather data should be read from tape and stored in file **d.weather.** The data should then be visually checked for completeness. Any year which does not contain a complete set of temperature or precipitation data must be deleted. While missing years are not a problem (provided both the temperature and the precipitation elements are absent), missing months within the data set could cause problems in a WYSPAC run.

Parameter Selection

To provide a water-yield estimation for any particular crop, soil type and irrigation regime, input parameters must be assigned appropriate values. File **d.param** contains a column of sample parameter values, to the right of which is a short description of each.

A more detailed description of each parameter is given below. Once the parameters to be entered have

been selected, the user should edit the parameter column in file **d.param.** The user is cautioned not to eliminate leading zeros from the parameter column.

1. Crop type

crop	parameter
tree fruits	1
grapes	2
alfalfa	3
wheat	4
corn	5
potatoes	6
sugar beets	7

2. Soil type

soil	parameter
sandy	1
sandy loam	2
silt-loam	3
organic	4

3. Expected crop life (years)

01 for annual crops up to a maximum of 25

4. *Expected maturation* (years)

01 for annual crops up to 25

5. *Beginning of growing season* (month)

range is 03 (March) through 12 (December)

6. *End of growing season* (month)

03 through 12

Note that valid months begin in March as the program is not equipped to handle February leap years.

7. *Number of runs desired*

This parameter allows annual crop simulations with a series of different weather years. For perennial crops (crops 1 and 2) only one run at a time is possible.

range is 01 through 20

8. *Initial soil water level*

This parameter sets the soil water level at the beginning of the season to a specified fraction of the soils' field capacity. Thus for a crop such as tree fruits, this parameter might be set to 1.00 whereas with an annual crop, the soil water level would necessarily be below field capacity to facilitate

planting.

range is 0.00 through 1.00

9. Type of irrigation pattern – how to be uppercase.

In recognition of the fact that different crops are generally irrigated using different irrigation patterns, 3 patterns are available in WYSPAC:

P : Periodic irrigation pattern. The user is able to specify up to 5 points during the growing season at which irrigation will occur.

R : Rotation irrigation pattern. The user must specify the number of continuing rotations as well as the start and finishing dates of irrigation.

S : Sufficient irrigation. This pattern assures adequate irrigation at all points during the growing season. Irrigation is supplied in an amount to maintain the soil water levels for crops 1 and 2 at 60% field capacity (FC), crops 3,4,5, and 7 at 50% of FC, and crop 6 at 65% FC.

10. For P type irrigation, the number of irrigations.

range 0 through 5

11. Timing of P type irrigations

Up to 5 numbers may be entered, each indicating when an irrigation should occur during the growing season. The values must fall within the relevant growing season time span. This is not a calendar date but rather a growing season day where the beginning of the growing season equals 001. Thus if the growing season began in month 04 (April) and an irrigation application was desired for May 15, then a value of 045 would be entered in one of the 5 available data fields. Data fields should be filled left to right.

12. Number of R type irrigation rotations

range 01 through 25

13. Amount of water applied per application (inches)

This applies only to P and R type irrigations.

range 00.000 through 99.999 inches

14. Water application efficiency factor relevant only for P or R irrigation

Different irrigation systems have different application efficiencies, the ratio of the amount of water which is made available to crops versus the amount of water actually applied. Below are listed some very rough application efficiency factor estimates for various irrigation systems:

system	parameter
trickle	1.00
centre pivot	0.72
travelling gun	0.72
sprinkler	0.75
stationary gun	0.65

15. Starting day for R type irrigation

This is not a calendar day but rather a growing season day. Thus if the growing season began in month 04 (April) and rotation type irrigation was to begin May 5, then this parameter should be set to 035.

range 001 to end of growing season

16. Ending day for R type irrigation

range 001 to end of growing season, but must be greater than or equal to parameter 15 above.

17. Number of years of weather data

Provided that the available weather data in any given year covers the period of the growing season as defined in 5 and 6 above, then that year can be defined as a weather year. Any years with gaps occurring within the period defined as the growing season should

be deleted from the weather data.

range 01 through 75

18. Seed for random number generator

Since random number generators return identical strings of random numbers upon consecutive calls with the same initial seed, this parameter should be altered with each WYSPAC estimation to avoid duplication of results.

range 001 through 999

Running WYSPAC

Once weather data has been read into file **d.weather** and scanned for missing records, and a selection of parameter values has been entered into file **d.param**, WYSPAC is ready to be run. WYSPAC can be run using a **FORTRAN** 77 compiler where the ~~object~~ source file is **wyspac.f.**

Results

The results of a WYSPAC run are written out to file **d.result.** File **d.result** gives the crop name, soil type, the period of the growing season, the irrigation type, and the initial amount of water in the soil (inches) at the start of the growing season. For rotation and periodic type irrigation, the total amount of irrigation water (inches) available for each run

(for annual crops) or crop year (for perennial crops) is also given. Below this information is a table with columns for crop year or run, expected yield as a percentage of a no stress case, amount of irrigation water used by the crop (inches), and the total rainfall during the growing season (inches). The final part of file **d.result** gives the average % yield and average amount of water used, together with their repective standard deviations, for all annual crop runs or over the life of the perennial crop. In the case of perennial crops, the averages are for mature years only.

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