Surface Irrigation Design, Water Quality Risk Assessment, & Irrigation Scheduling Tool

Global Design Team

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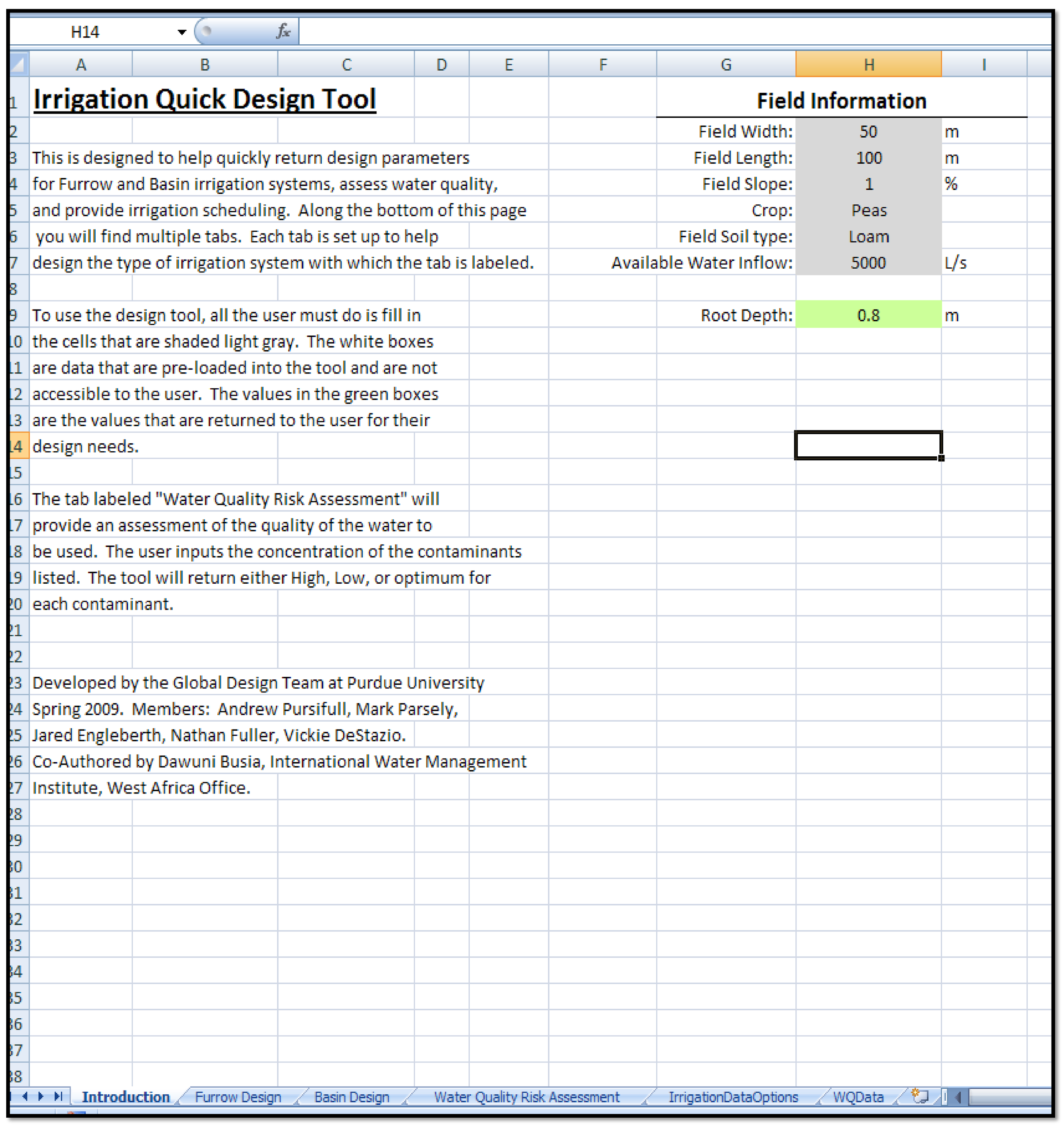
Quick Design & Assessment Tool

Getting Started

On the "Introduction" tab of the spreadsheet, users are given a concise description and tutorial of the software. Inputs for the model are kept basic in nature to ensure ease-of-use. Of course, design parameter outputs are only a computed suggestion and should be adapted to specific field conditions. The introduction page is shown in the screen capture to the right.



Irrigation Quick Design Tool

This is designed to help quickly return design parameters for Furrow and Basin irrigation systems, assess water quality, and provide irrigation scheduling. Along the bottom of this page you will find multiple tabs. Each tab is set up to help design the type of irrigation system with which the tab is labeled.

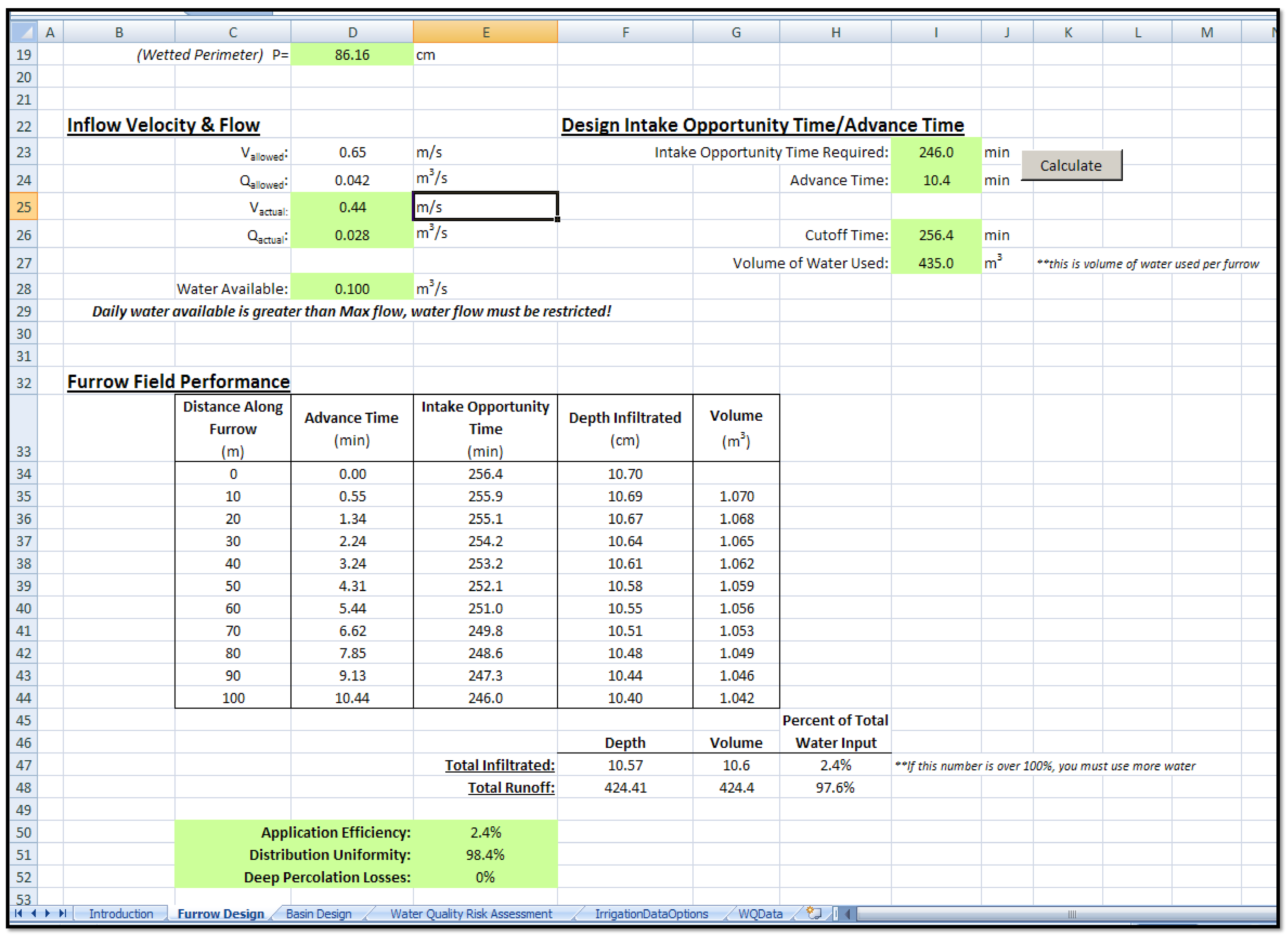
To use the design tool, all the user must do is fill in the cells that are shaded light gray. The white boxes are data that are pre-loaded into the tool and are not accessible to the user. The values in the green boxes are the values that are returned to the user for their design needs.

The tab labeled "Water Quality Risk Assessment" will provide an assessment of the quality of the water to be used. The user inputs the concentration of the contaminants listed. The tool will return either High, Low, or optimum for each contaminant.

Developed by the Global Design Team at Purdue University Spring 2009. Members: Andrew Pursifull, Mark Parsely, Jared Engleberth, Nathan Fuller, Vickie DeStazio. Co-Authored by Dawuni Busia, International Water Management Institute, West Africa Office.

Field Information		
Field Width:	50	m
Field Length:	100	m
Field Slope:	1	%
Crop:	Peas	
Field Soil type:	Loam	
Available Water Inflow:	5000	L/s
Root Depth:	0.8	m

Introduction | Furrow Design | Basin Design | Water Quality Risk Assessment | IrrigationDataOptions | WQData



(Wetted Perimeter) P= 86.16 cm

Inflow Velocity & Flow

$V_{allowed}$:	0.65	m/s
$Q_{allowed}$:	0.042	m^3/s
V_{actual}:	0.44	m/s
Q_{actual}:	0.028	m^3/s
Water Available:	0.100	m^3/s

Daily water available is greater than Max flow, water flow must be restricted!

Design Intake Opportunity Time/Advance Time

Intake Opportunity Time Required:	246.0	min
Advance Time:	10.4	min
Cutoff Time:	256.4	min
Volume of Water Used:	435.0	m^3

Calculate

***this is volume of water used per furrow*

Furrow Field Performance

Distance Along Furrow (m)	Advance Time (min)	Intake Opportunity Time (min)	Depth Infiltrated (cm)	Volume (m^3)
0	0.00	256.4	10.70	
10	0.55	255.9	10.69	1.070
20	1.34	255.1	10.67	1.068
30	2.24	254.2	10.64	1.065
40	3.24	253.2	10.61	1.062
50	4.31	252.1	10.58	1.059
60	5.44	251.0	10.55	1.056
70	6.62	249.8	10.51	1.053
80	7.85	248.6	10.48	1.049
90	9.13	247.3	10.44	1.046
100	10.44	246.0	10.40	1.042

	Depth	Volume	Percent of Total Water Input
Total Infiltrated:	10.57	10.6	2.4%
Total Runoff:	424.41	424.4	97.6%

***If this number is over 100%, you must use more water*

Application Efficiency:	2.4%
Distribution Uniformity:	98.4%
Deep Percolation Losses:	0%

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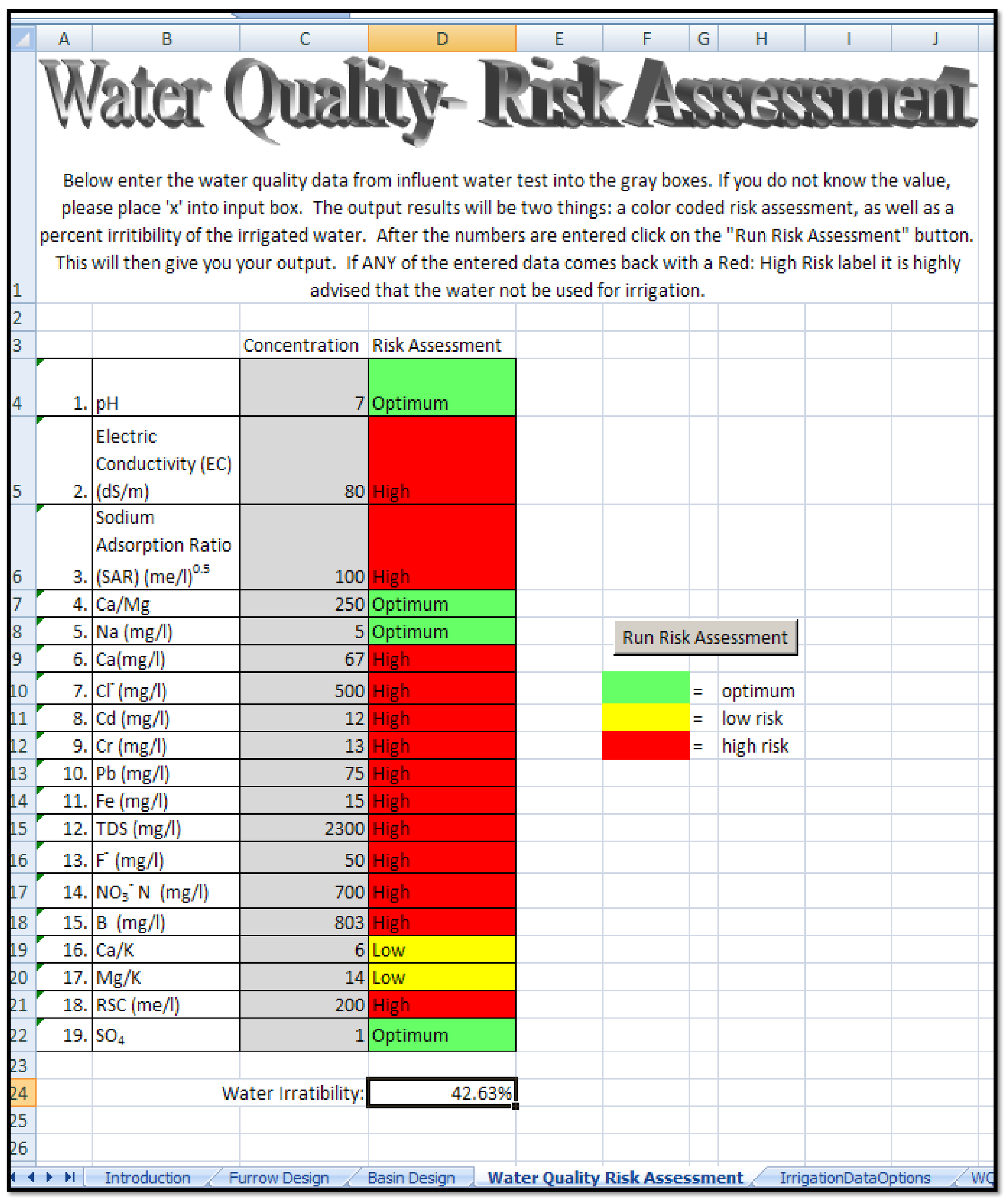
Results | User Input | Preloaded Data

INPUTS	OUTPUTS
Field Length	Max Velocity & Flow
Field Width	Intake Opportunity Time
Field Slope	Advance Time
Crop Type	Cutoff Time
Field Soil Type	Application Efficiency
Available Water Inflow	Distribution Uniformity

Surface Irrigation Design

In most instances the farmer knows what type of irrigation is best suited based on the crop being grown. The tool allows them to choose either furrow or basin irrigation, as these are the two most common types of irrigation used in under-developed countries that cannot afford sprinkler or drip systems.



Water Quality- Risk Assessment

Below enter the water quality data from influent water test into the gray boxes. If you do not know the value, please place 'x' into input box. The output results will be two things: a color coded risk assessment, as well as a percent irritibility of the irrigated water. After the numbers are entered click on the "Run Risk Assessment" button. This will then give you your output. If ANY of the entered data comes back with a Red: High Risk label it is highly advised that the water not be used for irrigation.

	Concentration	Risk Assessment
1. pH	7	Optimum
2. Electric Conductivity (EC) (dS/m)	80	High
3. Sodium Adsorption Ratio (SAR) $(me/l)^{0.5}$	100	High
4. Ca/Mg	250	Optimum
5. Na (mg/l)	5	Optimum
6. Ca(mg/l)	67	High
7. Cl^- (mg/l)	500	High
8. Cd (mg/l)	12	High
9. Cr (mg/l)	13	High
10. Pb (mg/l)	75	High
11. Fe (mg/l)	15	High
12. TDS (mg/l)	2300	High
13. F^- (mg/l)	50	High
14. NO_3^- N (mg/l)	700	High
15. B (mg/l)	803	High
16. Ca/K	6	Low
17. Mg/K	14	Low
18. RSC (me/l)	200	High
19. SO_4	1	Optimum

Water Irratibility: 42.63%

Run Risk Assessment

= optimum
= low risk
= high risk

Introduction | Furrow Design | Basin Design | Water Quality Risk Assessment | IrrigationDataOptions | WQ

Water Quality Risk Assessment

In addition to the development of the primary irrigation design spreadsheet, a water quality component has been added to provide a risk assessment of the irrigation water.

The user may enter pertinent information, such as pH and various chemical concentrations found in a water sample. If any outputs display a "High Risk" value, the water should be diluted to a safer level before use in irrigation.

Introduction

In developing countries, where food sources are limited, maximizing crop yield is essential to the survival and well-being of the local population. The Global Design Team (GDT) of Agricultural and Biological Engineering at Purdue University has been working in conjunction with the International Water Management Institute-West Africa Region to develop a master system in Microsoft Excel. This software package generates a variety output data which users can apply to find solutions for several common irrigation obstacles, including:

- Optimal design parameters for furrow and basin irrigation systems
- Risk assessment of irrigation water quality
- Suggested irrigation calendar

Locals in a rice field in Ghana, Africa. Courtesy of IWMI-West Africa

IWMI International Water Management Institute

Leadership through Global Engineering Program Global Impact

Global Design Team Specific Objectives:

- Develop software which outputs irrigation design parameters, irrigation water quality risk and a basic irrigation schedule.
- Ensure that the software is user-friendly by requiring only basic inputs and utilizing a streamlined layout.
- Communicate with contacts from IWMI's Ghana extension to help guide software development.

Irrigation Design

The primary source of information used to develop the GDT's master system is the Food and Agriculture Organization (FAO) of the UN. The FAO is the leader in the research and design of surface irrigation systems in Africa, hence their manual ***Guidelines for Designing and Evaluating Surface Irrigation Systems***. The GDT also referenced a spreadsheet developed by USDA Arid-Land Agricultural Research Center.

There are many factors that determine the design of a furrow or basin system. The object of the design is to optimize Application Efficiency (AE). Following are some of the equations

1) $$E_a = \frac{Z_{req} \cdot L}{Q_o \cdot t_{co}}$$

2) $$T_2 = T_1 + \frac{Z_{req} - kT_1^a - f_o T_1}{\frac{a \cdot k}{T_1^{1-a}} + f_o}$$

3) $$V_Z = W\int_0^L (k\tau^a + c\tau)dx$$

Eq. 1 was used to determine the Application Efficiency. It takes into account the required volume of water that must infiltrate, the length of the field, flow rate, and cutoff time. Eq. 2 is a basic equation that was manipulated to help determine the intake opportunity time. Both 1 & 2 came from the FAO's guidelines. Eq. 3 was found in the previously created spreadsheet which is manipulated to calculate the advance time. Eq. 3 comes from the American Society of Agricultural Engineers' Standards, standard EP419.1 DEC99.

Irrigation Scheduling

Methodology

The irrigation scheduling design spreadsheet uses the water balance model to compute a suggested irrigation calendar:

Irrigation + Rainfall = Evapotranspiration + Runoff + Deep Percolation + Soil Moisture Change

Evapotranspiration is calculated using the Penman-Monteith equation (FAO-56).

Necessary inputs, including parameters for effective rainfall, climate data, soil properties and crop characteristics are derived from empirical information supplied by FAO and IWMI.

Basic Inputs

Select the soil type for the field:	Loam	
Enter the management-allowed depletion of this available water before irrigation should begin. Higher allowed depletion allows less frequent irrigation but more risk of plant stress. Suggested value is 45%.	45	%
Select the approximate management-allowed soil moisture at the time of seeding: (Use 20% if unknown)	20	%
Select the crop to be irrigated:	Cassava (First Year)	
Select crop planting date:	5 January	
Select the area nearest to the field:	Ghana, Tamale	

Ghana, Salt Pond
Ghana, Sefwi Bekwai
Ghana, Takoradi
Ghana, Tamale
Ghana, Wa
Ghana, Wenchi
Ghana, Yendi
CUSTOM ENTRY

Month	Day	Irrigate Today?	Management-Allowed Remaining Water (mm)	Calculated Effective Rainfall (mm)	Actual Evapotranspiration (mm/day)	Development Day	Growth Stage	Day of Growth Stage	Effective Root Zone (m)	Crop Coefficient (K_c)
January	1	-----	-----	-----	-----	-----	-----	-----	-----	-----
January	2	-----	-----	-----	-----	-----	-----	-----	-----	-----
January	3	-----	-----	-----	-----	-----	-----	-----	-----	-----
January	4	-----	-----	-----	-----	-----	-----	-----	-----	-----
January	5	-----	3.78	-----	1.49	1	INITIAL	1	0.30	0.30
January	6	-----	2.29	-----	1.49	2	INITIAL	2	0.31	0.30
January	7	-----	0.79	-----	1.49	3	INITIAL	3	0.31	0.30
January	8	Irrigate	19.85	-----	1.49	4	INITIAL	4	0.32	0.30
January	9	-----	18.35	-----	1.49	5	INITIAL	5	0.32	0.30
January	10	-----	17.26	0.40	1.49	6	INITIAL	6	0.33	0.30
January	11	-----	15.76	-----	1.49	7	INITIAL	7	0.33	0.30
January	12	-----	14.27	-----	1.49	8	INITIAL	8	0.34	0.30
January	13	-----	12.77	-----	1.49	9	INITIAL	9	0.34	0.30

User Interface

Six basic inputs are required for output of an irrigation calendar: Soil type, management-allowed depletion, soil moisture at time of seeding, crop type, planting date, and location.

If no pre-listed options for a basic parameter are appropriate (i.e. a crop type isn't listed), users are able to enter custom information to best suit their needs.

When all basic inputs and any necessary custom inputs have been entered, users may click on the "Crop Calendar" tab to see a computed irrigation calendar. The calendar is based on a steady rainfall pattern and should be adjusted for adverse conditions.

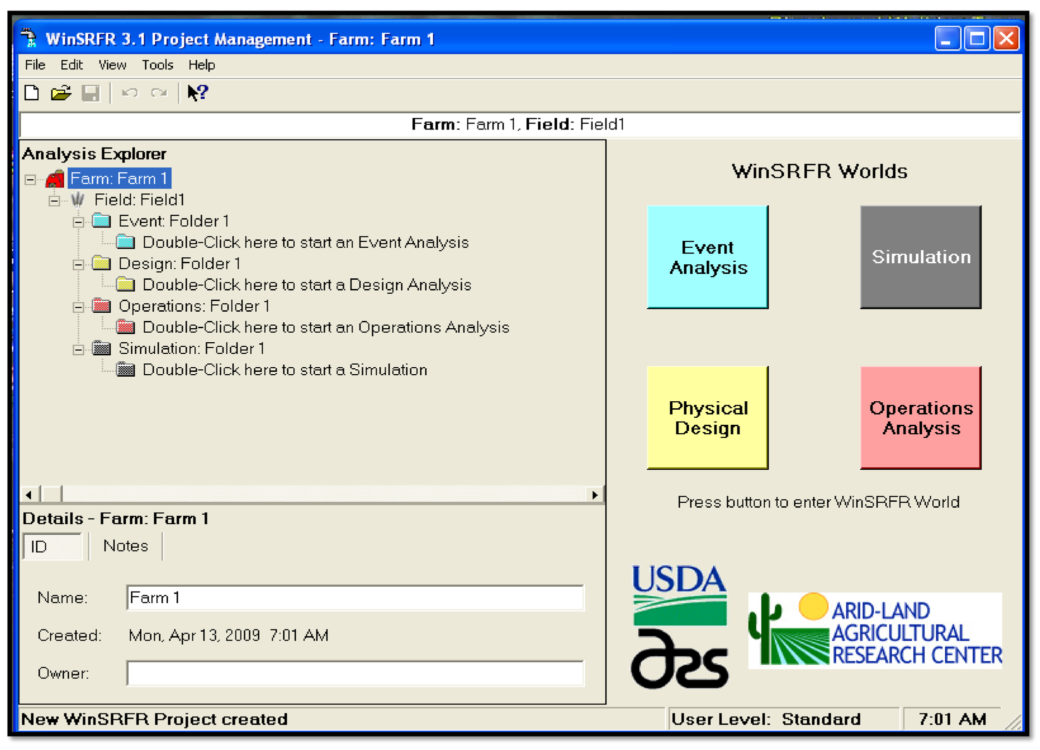
The calendar shown to the left is a sample of the output determined by the basic inputs entered in the above image.

Validation

With the main design of the program complete, we have now moved on to validating our program. We decided to test our program against one commonly used for furrow and basin design, WinSRFR 3.1 Project Management Tool. We have set up several case studies(some of which are shown to the right) and compare the results against one another.

With this information we have gone back and tweaked our program so that we are getting very similar answers out of both programs.

31										
32	Crop	SType	Inflow(L/s)	Fspacing(m)	TWidth(cm)	F Depth(cm)	DWater(cm)	Sim.(hrs)	Sim.(min)	Ours(min)
33	Soybeans	Silty Clay	1500	0.75	30	20	15	0.11	6.6	27.3
34	Soybeans	Clay	1000	1	40	30	22.5	0.04	2.4	5.4
35	Soybeans	Silty Clay Loam	1250	1	50	30	22.5	0.08	4.8	5.4



We decided to use the WinSRFR program because it is commonly used by the USDA and the Arid-Land Agricultural Research Center to improve on furrow design. We thank them for letting us use the program for comparison.

References & Acknowledgements

References

- Guidelines for Designing and Evaluating Surface Irrigation Systems. W. R. Walker, consultant to FAO (1989)
- ASAE Standards, 2000
- FAO Corporate Document Repository
- Clemmens, A.J., Journal of Land & Water, 2007, Vol. 1, 20-43

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