Instruction Manual for the Farm Agricultural Diagnostics (FAD) tool

Chapter 1. Descriptions of sheets

The Macro-enabled Excel Workbook FAD-v1.0.xlsm has multiple worksheets, summarized as follows:

S. No.	Worksheet Name	Description	User Input
1	AHP_Scale	Explains the Fundamental Scale used in the AHP (Saaty, 1980)	NA
2	Parameters_Soil	Soil parameters which are included in the SQI calculation, along with their ideal values. Maximum allowed = 14 parameters	Parameter names/abbreviations (Column A) Ideal value (Column B): choose out of "More" (higher parameter value is better) or "Less" (lower parameter value is better). If a particular parameter value is optimal (optimal pH = 7), do not choose any value and enter in 1_Data sheet (row 2), under the corresponding parameter name.
3	1_Data	Data of all farms is entered in this sheet.	Farmer names or farm identification (Column A)

		WUE data includes yield, rainfall, irrigation depth and number of irrigation application corresponding to the cropping season. SQI data includes all the soil parameter values for the parameters entered in the "Parameters_Soil" sheet. Each row represents a farm(er), and each column represents different values of the soil/water parameter values.	**Input data for WUE calculation:** Farm yield in kg/ha (Column B) Rainfall during cropping season in cm (Column C) Depth of single irrigation application in cm (Cell D2) Number of applied irrigations (Column D) **Input data for SQI calculation:** Soil parameter data for different parameters (Column E onwards - each column corresponds to each parameter mentioned in the "Parameters_Soil" sheet. If there is only 1 ideal value of the soil parameter (such as pH = 7), then mention that ideal value in the Cell under the parameter name. Example: If pH is the parameter name in Cell E1, then type "7" (its optimum value) in Cell E2.
4	2_Ranking	Assigns a basic ranking which represents relative importance of the SQI parameters	Assign rank to the SQI parameters in Column B (next to the parameter name in Column A). Start with 1 (against the subjectively "most important" parameter), and keep assigning till all parameters have been relatively ranked.
5	3_PWCM	Pair Wise Comparison Matrix (heuristics used in SQI calculation)	Assign relative importance between parameters, only in the upper triangular matrix (above the diagonal with 1

			values). Example: The respective cell value indicates how important the row parameter is relative to the column parameter. If the parameter in Row 2 is 4 times as important as the parameter in Column C, type "4/1" in Cell C2. If the parameter in Column C is 4 times as important as the parameter in Row 2, type "1/4" in Cell C2. The relative importance across the diagonal is automatically calculated. Use the AHP scale (Saaty, 1980) given in the "AHP_Scale" sheet to assign relative importances. Be careful to follow consistency rules as mentioned by Saaty (1980). If parameter x is 2 times more important than parameter y, and parameter y is 3 times more important than parameter z, then parameter x should be about 2x3 = 6 times as important as parameter z.
6	4_SQI	SQI has been calculated by running the "Main" macro	Results (SQI and ranked SQI) can be viewed by the user. No input.
7	5_WUE	WUE has been calculated by running the "Main"	Results (WUE) can be viewed by the user. No input.

		macro	
8	6_Results	Consolidated SQI and WUE data for each farm.	Results (SQI and WUE) are tabulated and can be viewed by the user. No input.
9	7_Classification	Classification	Farm classification based on SQI vs WUE performance into four performance zones - satisfactory performance (S), nutrient limited performance (NL), water limited performance (WL), and NLWL (nutrient and water co-limited performance). Results are tabulated and can be viewed by the user. No input.
10	8_Visualization	Chart with farm classification based on SQI vs WUE visualization.	Results (farm classification based on SQI vs WUE performance) are visualized in a 2-dimensional representation, with each point indicating an index (same as column A of Sheet "6_Results") corresponding to the farm. No input.

Chapter 2. Instructions to use the FAD tool

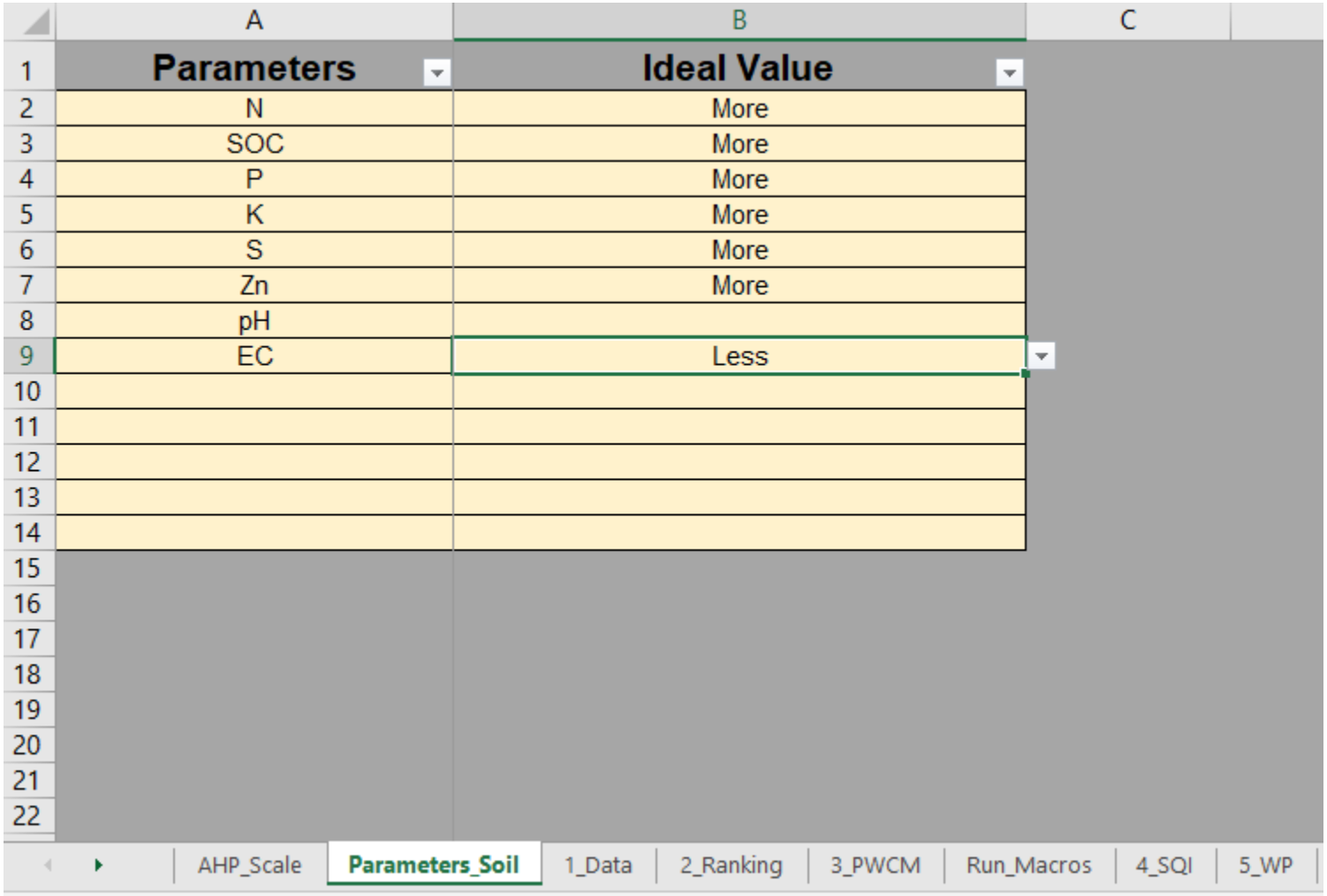
The user should input the data which is used by the tool to compute the soil and water related performance indicators - Soil Quality Index (SQI) calculated using the Analytic Hierarchy Process (Saaty, 1980), and Water Use Efficiency (WUE). The input data required, for each farm, is as follows:

- Input data for WUE:
    - Crop yield (kg/ha)
    - Rainfall during the cropping season (cm)
    - Average irrigation depth for one applied irrigation (cm)
    - Number of irrigations applied during the entire season (-).
- Input data or heuristics for SQI:
    - Values of the soil parameters tested (in their respective units).
    - Knowledge of the ideal parameter value, either qualitatively (less/more is better) or quantitatively (ideal pH value = 7)
    - Heuristics regarding how any two parameters are relatively important with respect to each other (in a consistent manner). For example, if organic carbon is 2 times more important than nitrogen, and nitrogen is 3 times more important than phosphorus, then organic carbon should be about 6 times more important than phosphorus, to maintain consistency.

Step 1: Enter soil parameter names for SQI and their ideal values in the "Parameters_Soil" sheet

- Enter the soil parameter names which have been tested and whose results are available for different farms, in Column A. The maximum number of parameters that can be entered is 14, based on a limitation of the AHP (Saaty, 1980).
- Enter their ideal values using the drop down list of each cell in Column B in case they are qualitatively defined. If a higher/lower

parameter value is better, select "More"/"Less" from the drop down list. If the parameter has a quantifiable ideal value (such as pH = 7), leave the corresponding cell in Column B empty.



	A	B	C
1	Parameters	Ideal Value	
2	N	More	
3	SOC	More	
4	P	More	
5	K	More	
6	S	More	
7	Zn	More	
8	pH		
9	EC	Less	
10			
11			
12			
13			
14			
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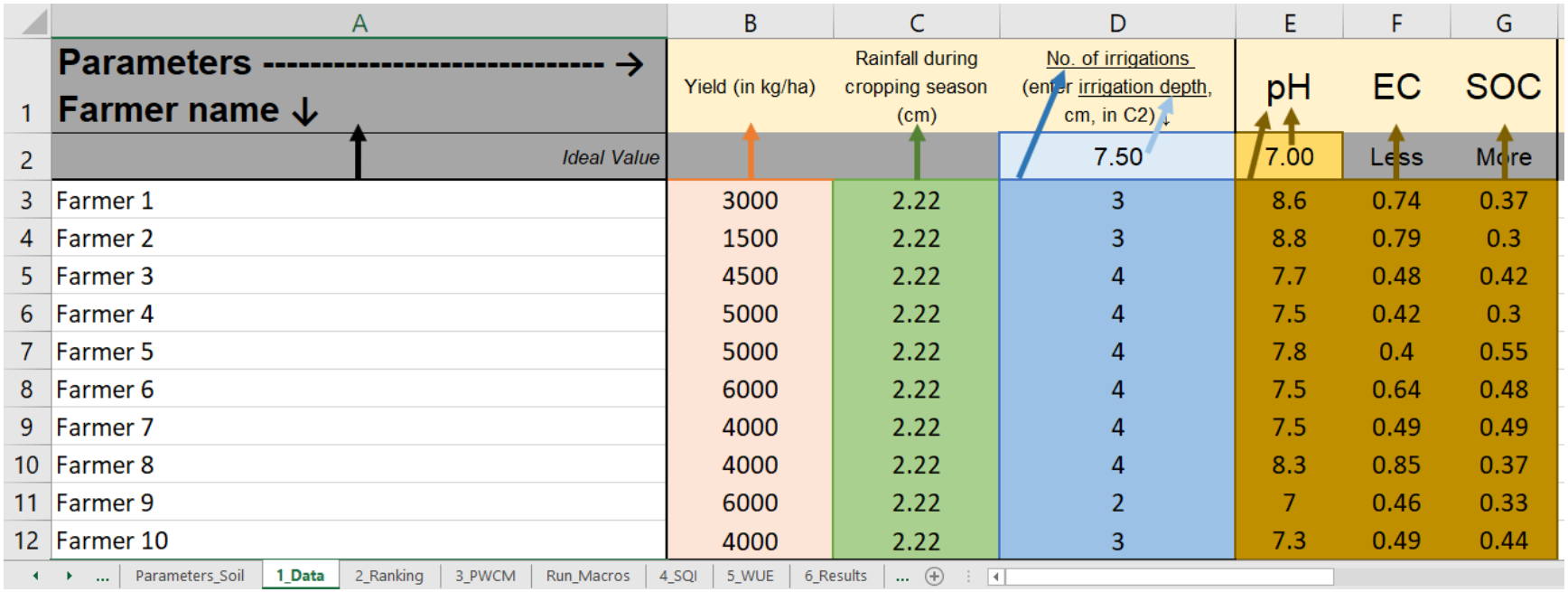
21			
22			

Figure 1: Screengrab of the "Parameters_Soil" sheet

Step 2: Enter input data for SQI and WUE calculation in the "1_Data" sheet

- Enter the farmer name or farm identification in Column A.
- Input data for WUE (Column B-D):
    - Enter Yield (kg/ha) in column B.
    - Enter the rainfall (cm) during the entire cropping season in Column C.
    - Number of irrigations and irrigation depth:
        - Enter the number of irrigations applied (-) in Column D, and the average depth of each irrigation in cell D2.
        - If farms have different average depths, enter "1" (cm) in cell D2, and the cumulative irrigation depth applied during the entire season in the rest of Column D.
- Input data for SQI (Column E onwards):
    - Choose one parameter for each cell (starting from E1) from the list of parameters mentioned in the "Parameters_Soil" sheet.
    - Populate the table with measured values of the corresponding parameter, from Column E onwards.
    - If a soil parameter has a quantifiable ideal value (such as Column E in the Figure 2), then enter the ideal value in the cell under the column header (in this case, cell E2). You will be prompted to re-enter this value while running the macros.



	A	B	C	D	E	F	G
1	**Parameters ----------→ Farmer name ↓**	Yield (in kg/ha)	Rainfall during cropping season (cm)	No. of irrigations (enter irrigation depth, cm, in C2) ↓	pH	EC	SOC
2	*Ideal Value*			7.50	7.00	Less	More
3	Farmer 1	3000	2.22	3	8.6	0.74	0.37
4	Farmer 2	1500	2.22	3	8.8	0.79	0.3
5	Farmer 3	4500	2.22	4	7.7	0.48	0.42
6	Farmer 4	5000	2.22	4	7.5	0.42	0.3
7	Farmer 5	5000	2.22	4	7.8	0.4	0.55
8	Farmer 6	6000	2.22	4	7.5	0.64	0.48
9	Farmer 7	4000	2.22	4	7.5	0.49	0.49
10	Farmer 8	4000	2.22	4	8.3	0.85	0.37
11	Farmer 9	6000	2.22	2	7	0.46	0.33
12	Farmer 10	4000	2.22	3	7.3	0.49	0.44

... | Parameters_Soil | 1_Data | 2_Ranking | 3_PWCM | Run_Macros | 4_SQI | 5_WUE | 6_Results | ...

Figure 2: Screengrab of the "1_Data" sheet.

Step 3: Sort parameters in the "2_Ranking" sheet

- Assign ranks to each of the soil parameters (listed in Column A), in Column B.
- A sorted parameter order appears automatically in Column C, as well as in the "3_PCWM" sheet.

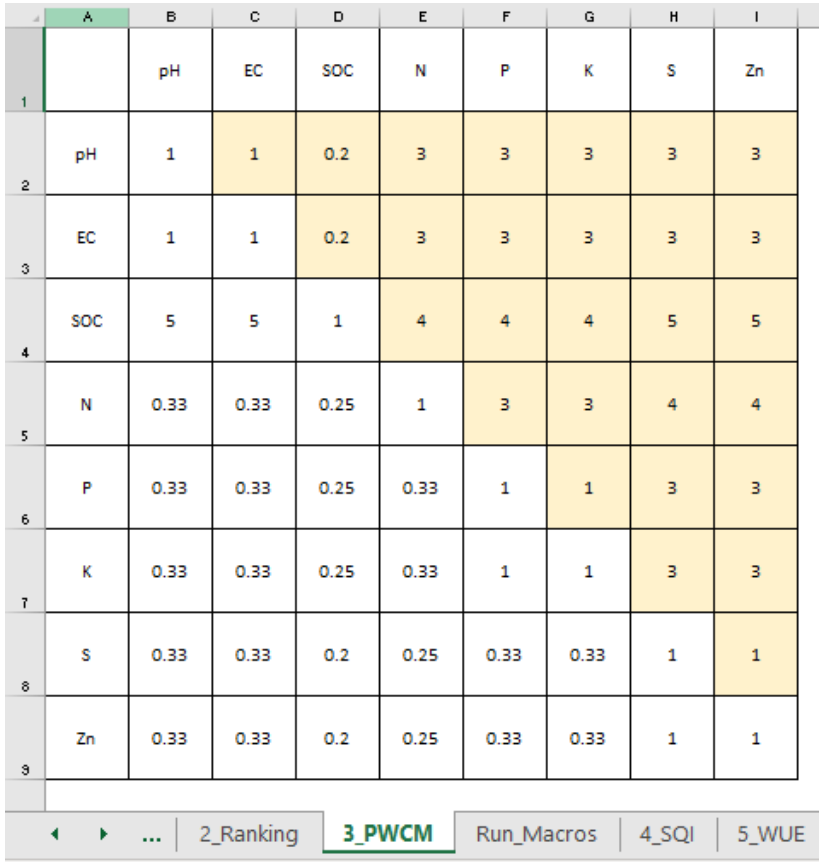
	A	B	C	D
1	**Parameters Chosen**	**Rank Assigned**	**Sorted Parameters**	
2	pH	8	S	
3	EC	6	P	
4	SOC	4	N	
5	N	3	SOC	
6	P	2	K	
7	K	5	EC	
8	S	1	Zn	
9	Zn	7	pH	
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				

... | Parameters_Soil | 1_Data | 2_Ranking | 3_PWCM | Run_Macros | 4_SQI | 5_WUE | 6_Results | ...

Figure 3: Screengrab of the "2_Ranking" sheet.

Step 4: Assign relative importances in the "3_PWCM" sheet

- A PWCM (Pair Wise Comparison Matrix, Saaty, 1980) is generated in the "3_PWCM" sheet.
- Enter the relative importance of each parameter with respect to the other, on the upper triangular matrix (all the cells highlighted in orange, in Figure 4). Use the Fundamental Scale (Saaty, 1980) given in the "AHP_Scale" sheet.
- For example, in Figure 4, pH is of equal importance as EC (cell C2 = 1), pH is 3 times as important as N (cell E2 = 3), and SOC is 5 times as important as pH (cell D2 = 1/5 or 0.2)



	A	B	C	D	E	F	G	H	I
1		pH	EC	SOC	N	P	K	S	Zn
2	pH	1	1	0.2	3	3	3	3	3
3	EC	1	1	0.2	3	3	3	3	3
4	SOC	5	5	1	4	4	4	5	5
5	N	0.33	0.33	0.25	1	3	3	4	4
6	P	0.33	0.33	0.25	0.33	1	1	3	3
7	K	0.33	0.33	0.25	0.33	1	1	3	3
8	S	0.33	0.33	0.2	0.25	0.33	0.33	1	1
9	Zn	0.33	0.33	0.2	0.25	0.33	0.33	1	1

Figure 4: Screengrab of the "3_PWCM" sheet.

Step 5: Run Macros, generate results and visualization

- Run the appropriate Macro to avail the diagnostics results. Go to the sheet "Run_Macro", and choose from the following:
    - **"Individual Components" group:** Click on these macros to compute each individual component of the entire FAD tool one at a time, i.e.
        - Compute Soil Indicator (SQI): click this to only compute SQI of each farm; results displayed in sheet "4_SQI".
        - Compute Water Indicator (WUE): click this to only compute WUE of each farm; results displayed in sheet "5_WUE".
        - Compile All Results: click this to compile SQI and WUE results in sheet "6_Results". Please make sure that you have computed SQI and WUE (using the above two buttons), since this macro cannot run on its own and depends on their results. You will be reminded to run the above two macros, with user prompts.
        - Classify farms based on Performance (sheet "7_Classification"): click this to create a tabular classification of farm performance, into the 4 performance zones - satisfactory performance (S), nutrient limited performance (NL), water limited performance (WL), and NLWL (nutrient and water co-limited performance).
        - Visualize Results: click this to create a visual representation of the farm performance based on the above zones (S, NL, WL, and NLWL). Please make sure you have deleted sheet "8_Visualization" before you run this macro otherwise the chart will not be successfully created.
    - **"All Components" group:** Click on the "Run FAD (all above steps)" macro button to run all the above steps in a sequential manner. Please make sure you have deleted sheet "8_Visualization" before you run this macro otherwise the chart will not be successfully created.
    - **"Clean up" group:** Click on the "Clean up User Inputs" macro button to clean up user inputs from each individual sheet. You will be prompted to choose what you would like to clean up, including:
        - parameter choices on sheet "1_Data",
        - parameter rankings on sheet "2_Ranking",
        - pair wise comparison matrix on "3_PWCM", and
        - all the results, in sheets "4_SQI", "5_WUE", "6_Results" and "7_Classification".

The macro does not clean up the farm input data on sheet "1_Data", and that has to be deleted manually by you itself.

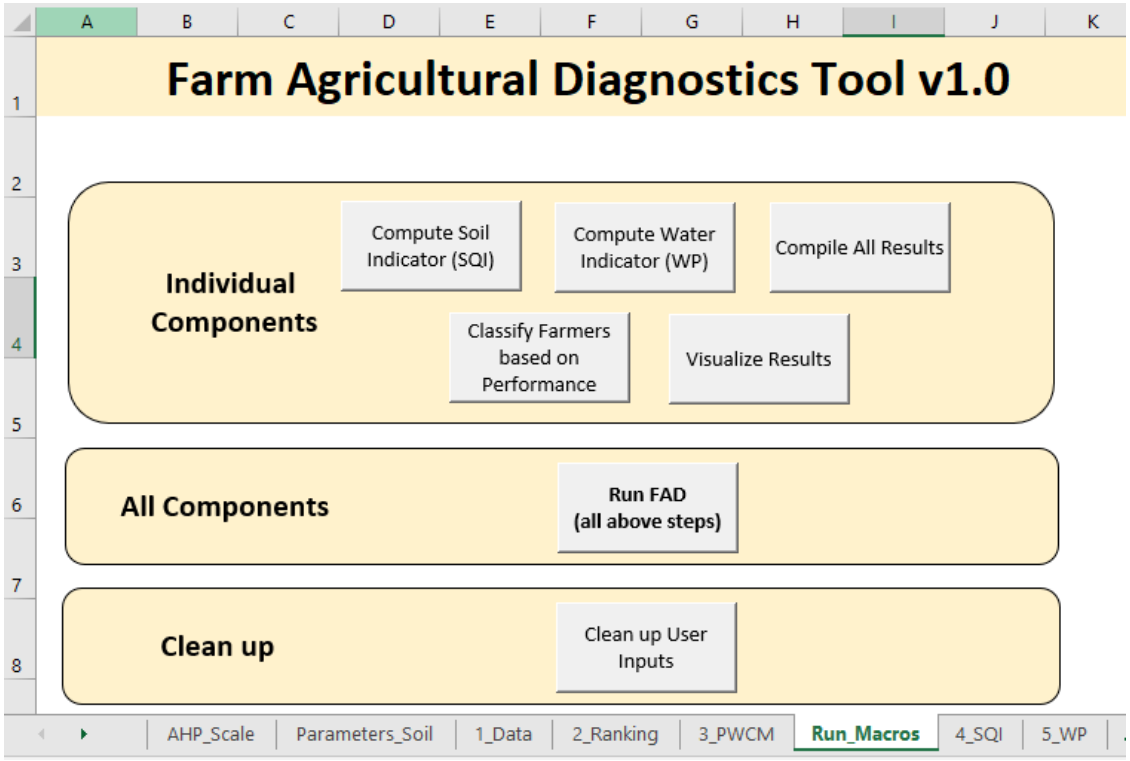


Figure 5: Screengrab of the "Run_Macros" sheet.

Step 5: View results and visualization

After running the macros, you can view the following results as follows:

- **Result 1:** Table of all the SQI values (and ranked SQI values) of all the farms (in sheet "4_SQI").

	A	B	C	D	E	F	G	H
1	Soil Quality Index (%)					Farmers ranked by Soil Quality Index (%)		
2	Rank	Farmer Name or ID	SQI			Rank	Farmer Name or ID	Ranked SQI
3	23	Farmer 1	48.919			1	Farmer 43	77.163
4	33	Farmer 2	45.672			2	Farmer 63	76.76
5	11	Farmer 3	57.381			3	Farmer 62	66.598
6	17	Farmer 4	51.947			4	Farmer 59	66.333
7	5	Farmer 5	65.032			5	Farmer 5	65.032
8	8	Farmer 6	58.145			6	Farmer 7	62.9
9	6	Farmer 7	62.9			7	Farmer 12	61.13
10	18	Farmer 8	51.893			8	Farmer 6	58.145
11	15	Farmer 9	52.892			9	Farmer 10	57.563
12	9	Farmer 10	57.563			10	Farmer 17	57.454
13	24	Farmer 11	48.857			11	Farmer 3	57.381
14	7	Farmer 12	61.13			12	Farmer 58	56.077
15	14	Farmer 13	53.575			13	Farmer 23	55.585
16	35	Farmer 14	43.74			14	Farmer 13	53.575
17	30	Farmer 15	46.54			15	Farmer 9	52.892
18	36	Farmer 16	43.626			16	Farmer 61	52.162
19	10	Farmer 17	57.454			17	Farmer 4	51.947
20	19	Farmer 18	51.312			18	Farmer 8	51.893
21	32	Farmer 19	46.202			19	Farmer 18	51.312
22	49	Farmer 20	37.702			20	Farmer 25	50.822

... | Parameters_Soil | 1_Data | 2_Ranking | 3_PWCM | Run_Macros | 4_SQI | 5_WUE | 6_Results | ...

Figure 6: Screengrab of the "4_SQI" sheet.

- **Result 2:** Table of the WUE values (kg/m^3) of all the farms (in sheet "5_WUE").

	A	B	C
2	**Index**	**Farmer Name**	**WUE**
3	1	Farmer 1	1.213592233
4	2	Farmer 2	0.606796117
5	3	Farmer 3	1.396648045
6	4	Farmer 4	1.551831161
7	5	Farmer 5	1.551831161
8	6	Farmer 6	1.862197393
9	7	Farmer 7	1.241464929
10	8	Farmer 8	1.241464929
11	9	Farmer 9	3.484320557
12	10	Farmer 10	1.618122977
13	11	Farmer 11	2.022653722
14	12	Farmer 12	1.551831161
15	13	Farmer 13	1.241464929
16	14	Farmer 14	1.086281813
17	15	Farmer 15	0.931098696
18	16	Farmer 16	1.862197393
19	17	Farmer 17	1.862197393
20	18	Farmer 18	1.396648045
21	19	Farmer 19	1.551831161
22	20	Farmer 20	1.011326861
23	21	Farmer 21	2.022653722

... | 3_PWCM | Run_Macros | 4_SQI | **5_WUE** | 6_F

Figure 7: Screengrab of the "5_WUE" sheet.

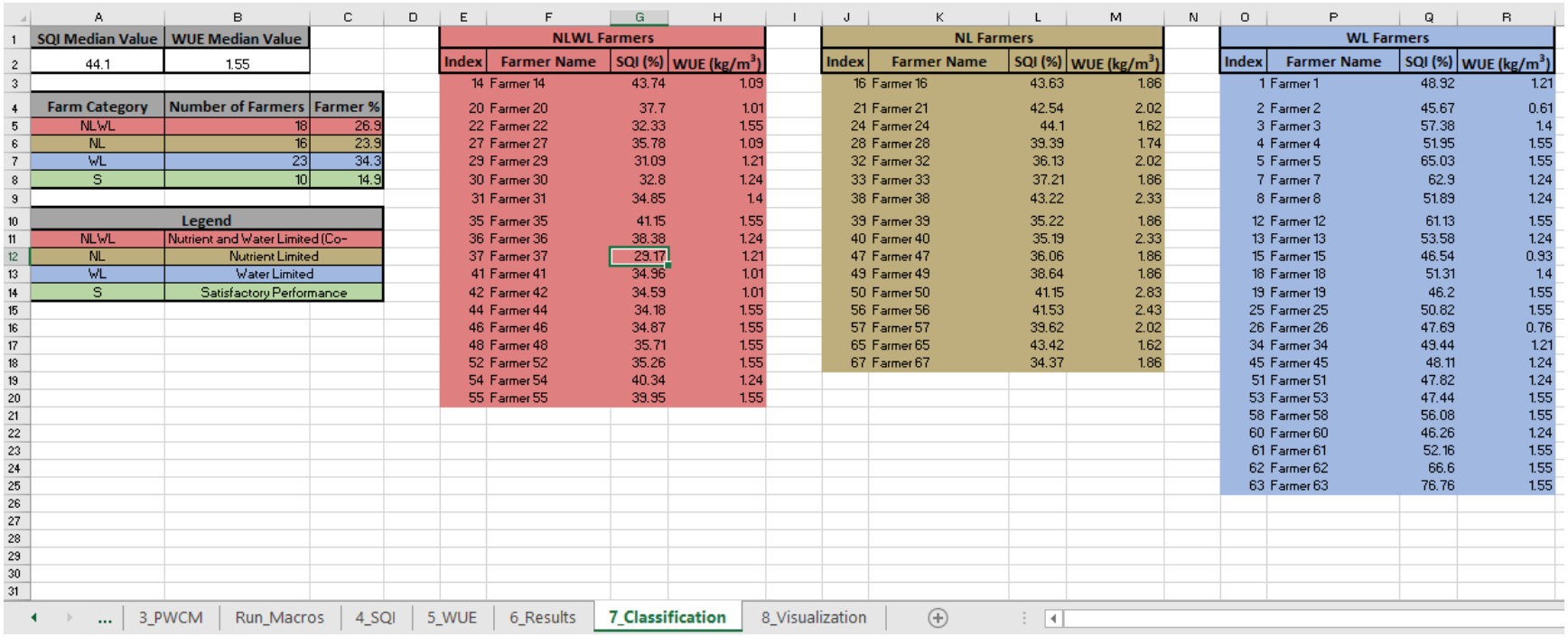
- **Result 3:** Table of the consolidated results of SQI (%) and WUE (kg/m^3) of all the farms (in sheet "6_Results").

	A	B	C	D
1	Index	Farmer Name	SQI (%)	WUE (kg/m^3)
2	1	Farmer 1	48.92	1.21
3	2	Farmer 2	45.67	0.61
4	3	Farmer 3	57.38	1.4
5	4	Farmer 4	51.95	1.55
6	5	Farmer 5	65.03	1.55
7	6	Farmer 6	58.14	1.86
8	7	Farmer 7	62.9	1.24
9	8	Farmer 8	51.89	1.24
10	9	Farmer 9	52.89	3.48
11	10	Farmer 10	57.56	1.62
12	11	Farmer 11	48.86	2.02
13	12	Farmer 12	61.13	1.55
14	13	Farmer 13	53.58	1.24
15	14	Farmer 14	43.74	1.09
16	15	Farmer 15	46.54	0.93
17	16	Farmer 16	43.63	1.86
18	17	Farmer 17	57.45	1.86
19	18	Farmer 18	51.31	1.4
20	19	Farmer 19	46.2	1.55
21	20	Farmer 20	37.7	1.01
22	21	Farmer 21	42.54	2.02

... | 3_PWCM | Run_Macros | 4_SQI | 5_WUE | 6_Results

Figure 8: Screengrab of the "6_Results" sheet.

- **Result 4:** Tabular classification of all the farms based on their SQI-WUE performance, into the following zones: satisfactory (S), nutrient limited (NL), water limited (WL), nutrient and water co-limited (NLWL), in sheet "7_Classification".



SQI Median Value	WUE Median Value
44.1	1.55

Farm Category	Number of Farmers	Farmer %
NLWL	18	26.9
NL	16	23.9
WL	23	34.3
S	10	14.9

Legend	
NLWL	Nutrient and Water Limited (Co-
NL	Nutrient Limited
WL	Water Limited
S	Satisfactory Performance

NLWL Farmers

Index	Farmer Name	SQI (%)	WUE (kg/m^3)
14	Farmer 14	43.74	1.09
20	Farmer 20	37.7	1.01
22	Farmer 22	32.33	1.55
27	Farmer 27	35.78	1.09
29	Farmer 29	31.09	1.21
30	Farmer 30	32.8	1.24
31	Farmer 31	34.85	1.4
35	Farmer 35	41.15	1.55
36	Farmer 36	38.38	1.24
37	Farmer 37	29.17	1.21
41	Farmer 41	34.96	1.01
42	Farmer 42	34.59	1.01
44	Farmer 44	34.18	1.55
46	Farmer 46	34.87	1.55
48	Farmer 48	35.71	1.55
52	Farmer 52	35.26	1.55
54	Farmer 54	40.34	1.24
55	Farmer 55	39.95	1.55

NL Farmers

Index	Farmer Name	SQI (%)	WUE (kg/m^3)
16	Farmer 16	43.63	1.86
21	Farmer 21	42.54	2.02
24	Farmer 24	44.1	1.62
28	Farmer 28	39.39	1.74
32	Farmer 32	36.13	2.02
33	Farmer 33	37.21	1.86
38	Farmer 38	43.22	2.33
39	Farmer 39	35.22	1.86
40	Farmer 40	35.19	2.33
47	Farmer 47	36.06	1.86
49	Farmer 49	38.64	1.86
50	Farmer 50	41.15	2.83
56	Farmer 56	41.53	2.43
57	Farmer 57	39.62	2.02
65	Farmer 65	43.42	1.62
67	Farmer 67	34.37	1.86

WL Farmers

Index	Farmer Name	SQI (%)	WUE (kg/m^3)
1	Farmer 1	48.92	1.21
2	Farmer 2	45.67	0.61
3	Farmer 3	57.38	1.4
4	Farmer 4	51.95	1.55
5	Farmer 5	65.03	1.55
7	Farmer 7	62.9	1.24
8	Farmer 8	51.89	1.24
12	Farmer 12	61.13	1.55
13	Farmer 13	53.58	1.24
15	Farmer 15	46.54	0.93
18	Farmer 18	51.31	1.4
19	Farmer 19	46.2	1.55
25	Farmer 25	50.82	1.55
26	Farmer 26	47.69	0.76
34	Farmer 34	49.44	1.21
45	Farmer 45	48.11	1.24
51	Farmer 51	47.82	1.24
53	Farmer 53	47.44	1.55
58	Farmer 58	56.08	1.55
60	Farmer 60	46.26	1.24
61	Farmer 61	52.16	1.55
62	Farmer 62	66.6	1.55
63	Farmer 63	76.76	1.55

Figure 9: Screengrab of the "7_Classification" sheet.

- **Result 5:** Combined SQI-WUE visualization corresponding to the classification ("7_classification"), given in graphical form, in sheet "8_Visualization".

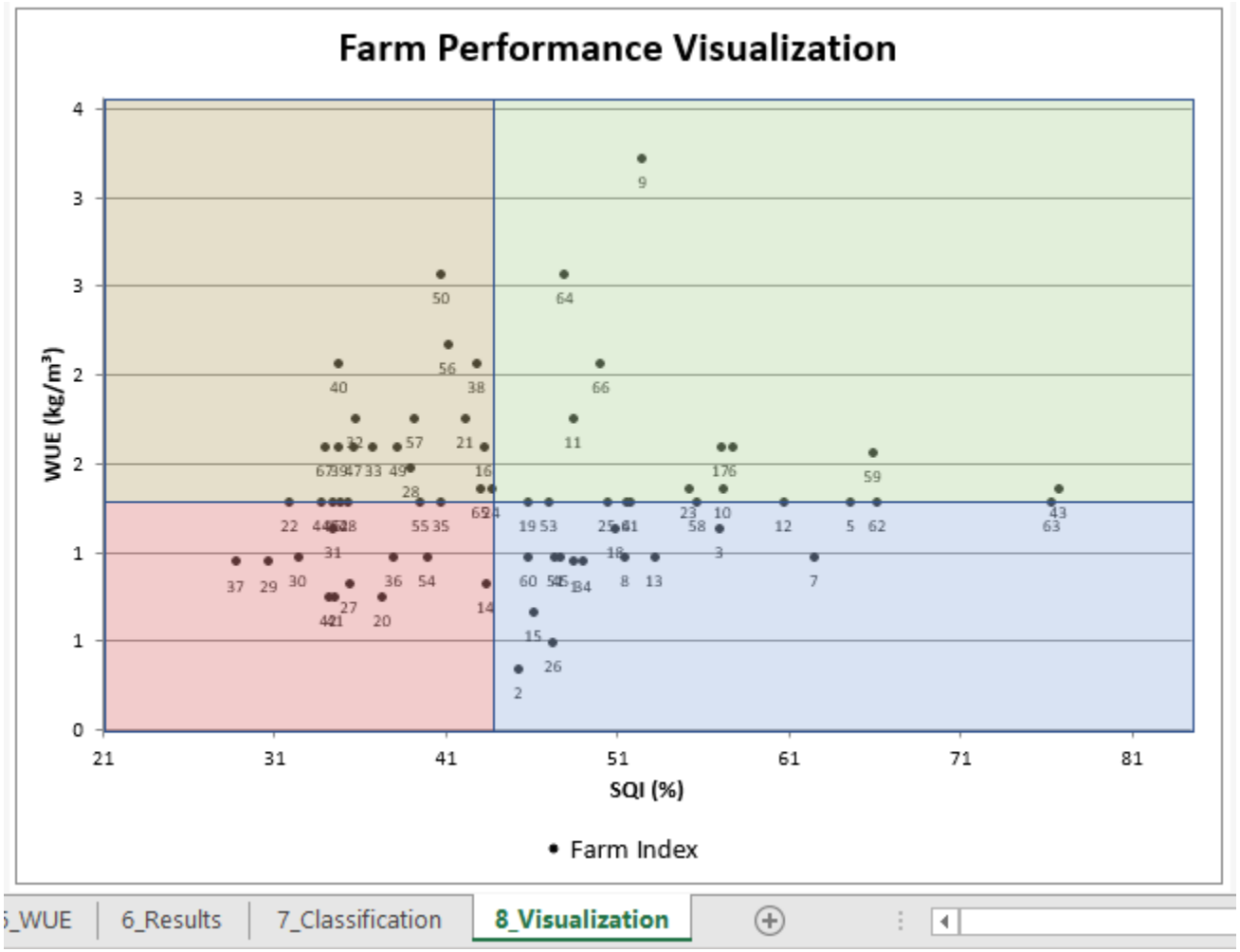


Figure 10: Screengrab of the "8_Visualization" sheet