Some User-friendly User-interface Computer Techniques for Improving Agrometeorological Bulletins

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Abstract

The Agrometeorology department of the Israel Meteorological Service issues a 10-day report and twice-weekly estimates of evapotranspiration based on data collected from several automatic weather stations. Both products make extensive use of the popular Excel spreadsheet software, and in particular, the user-friendly pivot table and input table utilities. These modules are normally used in financial applications, but it is shown that they have great potential in agrometeorology, and are well worth exploring in light of the widespread availability of the necessary low-cost software and desktop computers. As with most spreadsheet applications no programming skills are required even though the two features are quite powerful. The methodology is discussed, and the use and effectiveness of the techniques are demonstrated. Specifically, it is shown that *what-if* input tables may be easily adapted to analyze relatively complex derived evapotranspiration estimates, and pivot tables may be used to considerably simplify the processing and organization of agrometeorological databases.

Introduction

Spreadsheet techniques have advanced significantly in recent years in tandem with increasing computer power. Microsoft Excel now includes a utility, which generates what-if tables and another, which generates pivot tables. Extensive documentation on these techniques indicates that they are primarily designed for financial applications. Nevertheless, they can easily be adapted to function in scientific applications. In agrometeorology the analysis of potential evapotranspiration as derived from several meteorological inputs serves as a good example to demonstrate the power and use of the what-if utility. The table, which is calculated by this module, may be interpreted as a calculated field in an agrometeorological database. It therefore extends the usefulness of the pivot table utility which enables

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users to design reports, including statistical analyses, based on moderately-sized databases. The techniques are illustrated with the goal of providing useful low-cost tools for processing and improving agrometeorological products.

What-If Input Tables

Test Case - Potential Evapotranspiration

The usefulness of the *what-if table* Excel utility lies in its ability to reduce a relatively complex set of calculations applied repeatedly to a set of inputs from records in a database without requiring any programming or programming experience. It is therefore particularly suited to the determination of potential evapotranspiration based on the combination method originally developed by Penman (1948), because of its importance as a physically-based model and its relative complexity requiring several meteorological inputs. It is worthwhile therefore giving a brief description of the model, specifically the Penman-Monteith generalization, which estimates the potential evapotranspiration from un-wetted vegetation. Its importance as a tool in estimating crop water requirements as compared with other methods has been well documented (Jensen *et al.* 1990). A general form of the Penman-Monteith equation is given as

$$PM = \frac{\Delta(R_n - G)/L + \gamma E_a}{\Delta + \gamma(1 + r_s/r_a)} \tag{1}$$

where R_n and G are the net radiation and soil heat fluxes respectively, with units of MJ m^{-2} day^{-1}, E_a is the aerodynamic component of the potential evapotranspiration PM, both in mm day^{-1} and L = 2.45 MJ kg^{-1} (or, equivalently, MJ m^{-2}) is the latent heat of vaporization. In eq. (1), Δ is the slope of the saturation vapor pressure with temperature and γ is the psychrometric constant, both measured in units of kPa ^{o}C^{-1}, (at sea level, γ = kPa ^{o}C^{-1}); r_s and r_a are crop and aerodynamic resistances respectively, in s m^{-1}. The expression is quite general and physically-based including the crop resistance factor which parameterizes the unsaturated air humidity status adjacent to an un-wetted crop as compared with the saturated status over water or wetted surfaces.

Reference Potential Evapotranspiration

Allen *et al.* (1998) provide a detailed guide for calculating crop water requirements, using as a basis the atmospheric water demand,

estimated by the Penman-Monteith combination method, of a hypothetical reference crop. The standard crop is assumed to be a well-watered extended short grass 12 cm high, with 23% albedo and crop resistance r_s of 70 s m^{-1}. The aerodynamic resistance r_a, modeled from classic turbulent diffusion theory and neutral stability, is given as 208 U^{-1}, where U is the wind speed in m s^{-1} at standard 2m screen height. With these aerodynamic and crop specifications, the Penman-Monteith equation becomes with 1-day time steps

$$PM_{ref} = \frac{\Delta(R_n - G) + \gamma \dfrac{900}{T_K} U(e_s - e_a)}{\Delta + \gamma(1 + 0.34U)} \qquad (2)$$

where PM_{ref} is the reference evapotranspiration (mm day^{-1}), R_n and G are now given in equivalent evaporation units (mm day^{-1}), T_k is the air temperature at 2m (^{o}K) and e_s and e_a are the saturation and actual vapor pressures (kPa).

For the 1-day time step, the soil heat flux may be ignored, and Δ is easily calculated as an analytic non-linear function of air temperature. The vapor deficit e_s-e_a may be calculated from temperature measurements along with a humidity observation, such as wet-bulb temperature, relative humidity or dew-point; γ is proportional to atmospheric pressure, and in the absence of barometric data, it is sufficient to use an average based on the standard pressure corresponding to the station elevation.

The net radiation may be written as

$$R_n = (1 - \alpha)R_s - R_{nl} \qquad (3)$$

where R_s is the global radiation, $\alpha = 0.23$ is the albedo, and R_{nl} is the net long-wave radiation. Assuming the latter is not measured directly or calculated from soundings, a suitable semi-empirical expression for R_{nl} may be used depending on temperature and humidity at screen height, and sunshine duration (e.g. the Brunt formulation), the latter acting effectively as a surrogate for cloud cover. Furthermore, sunshine duration may also be used as surrogate for global radiation R_s if the latter is not measured directly; for example, the well-known Angstrom expression R_s / R_s = a + b (n / N) may be employed where a and b are regression coefficients and n is the sunshine duration. The day-length N and the daily extraterrestrial daily solar input R_{sa} may be calculated analytically from astronomical relationships as a function of station latitude and day of the

year. Thus, PM_{ref} may be determined from eq. (2) with observations of temperature, humidity, wind and sunshine duration as a surrogate for radiation observations, which are lacking at many meteorological stations. It is highly recommended that users refer to the paper of Allen *et al.* (1998) which provides explicit instructions for calculating reference potential evapotranspiration from the available weather data, with useful discussions of data integrity and alternative methods, including various techniques for handling missing data.

One-Input What-If Table

From the previous discussion we note that the daily estimation of PM_{ref} may be obtained from 6 inputs - daily values of maximum and minimum temperatures and humidities, wind run and sunshine duration. As a derived quantity, the calculation of PM_{ref} is straightforward but cumbersome. A computer program written in any high-level language is an easy and logical way to perform the calculations. But this approach is hardly necessary today given the widespread availability of spreadsheet software which obviates the need for programming and which has built-in visual and interactive capabilities and flexible input formats and requirements. Table 1 shows a typical database for making PM_{ref} calculations; the 6 meteorological inputs are given for generic stations *StnA, StnB* etc. on specific dates in the first 8 columns. If the PM_{ref} estimation, which appears as output in the 10th column, were as simple, for example, as calculating the average temperature $T_{avg}=(T_{max}+T_{min})/2$, then the formula would be entered into the first record under the database heading *PM$_{ref}$* and then propagated downward through the database using the standard *Copy* procedure. In this case, however, several intermediate calculations are required; an obvious solution would be to introduce several auxiliary columns for these intermediate steps. This is a cumbersome approach, which may also be constrained by memory limitations, especially when the calculations are made for several hundreds or thousands of records.

The Excel *Table* utility within the *Data* main menu is a powerful utility which allows the user to carry out repeated PM_{ref} calculations without employing the *Copy* command; specifically, the calculation is carried out only once with the inputs from the first set of data inputs below the database headings. The repeated calculations for the remaining records are carried out by using pointers to subsequent inputs based on the record number. The counter or index is numbered 2,3,4, etc. in the 9th column with heading *Rec* in Table 1 and is an essential part of the *What-If* Excel utility. In a sense, the the *Rec* column is analogous to the "Do Loop" counter or index used in

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Tx	Tn	U	RHn	RHx	SD	Stn	Date	Rec	PM$_{ref}$
17.3	6.3	1.7	58	95	6.3	StnA	2001-01-11	2	1.5
17.5	6.2	2.2	57	93	4.7	StnA	2001-01-12	3	1.6
19.5	4.0	2.4	38	88	6.7	StnA	2001-01-13	4	2.3
20.2	8.8	5.1	30	73	7.6	StnA	2001-01-14	5	3.9
21.2	8.8	4.9	27	69	7.4	StnA	2001-01-15	6	4.2
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		.							
37.4	16.9	3.0	14	67	13.7	StnA	2001-06-21	10	9.1
33.4	18.1	3.9	24	74	13.5	StnA	2001-06-22	11	8.6
29.1	18.3	4.8	32	78	14.2	StnA	2001-06-23	12	7.9
30.4	17.0	3.9	44	82	14.2	StnA	2001-06-24	13	7.2
30.2	17.7	4.8	27	88	14.2	StnA	2001-06-25	14	8.2
		.							
		.							
		.							
19.6	8.0	1.9	66	97	4.8	StnB	2001-01-11	18	1.4
19.1	10.4	1.8	55	97	2.8	StnB	2001-01-12	19	1.5
20.5	6.2	2.1	44	97	5.5	StnB	2001-01-13	20	1.9
22.1	5.3	1.6	36	96	6.3	StnB	2001-01-14	21	1.9
23.6	4.6	2.1	30	93	7.0	StnB	2001-01-15	22	2.5
20.2	6.2	2.2	59	92	4.4	StnB	2001-01-16	23	1.7

Field symbols: T_x, T_n maximum and minimum temperatures (°C); U windspeed (m s^{-1}); RH_n, RH_x minimum and maximum relative humidities (%); SD sunshine duration (hr).

Table 1: Input and output of Penman-Monteith PM$_{ref}$ evapotranspiration calculation.

high-level programming. For convenience, the database, including the headings, is given the name *db* and the first counter with value 2 below the Rec heading is given the name *Rec*. Calculations of PM$_{ref}$ are then carried out, preferably in a separate dedicated calculator worksheet, with the 8 data inputs associated with the single index value *Rec*=2. In the calculator area, the maximum temperature Tx for the first record is retrieved using =*Index(db,Rec,1)*, since it is in the 1st column and the *Rec* or 2nd row. Similarly, =*Index(db,Rec,2)* points to the minimum temperature Tn, and =*Index(db,Rec,3)* to the wind speed U etc.. for the first data record. Time-independent inputs may be inserted into the calculator worksheet using a

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separate meta-table. Table 2 is defined as *Meta*; thus required inputs such as station latitude and elevation may be inserted into the calculator worksheet using expressions such as *=Vlookup(Index(db,Rec,7),Meta 2)* and *Vlookup(Index(db,Rec,7),Meta,3)* respectively.

Station	Latitude	Elevation	Anemometer height	Angstrom a	Angstrom b
	Deg (N)	m	m		
StnA	33	375	3	0.25	0.5
StnB	32	30	10	0.25	0.5
StnC	31	195	10	0.25	0.5

Coefficients a and b in $R_s/R_{sa} = a + b(n/N)$ relate global radiation R_s to n, sunshine Duration to extraterrestrial radiation

Table 2: Sample metadata for PM$_{ref}$ evapotranspiration calculation

The 8 inputs from the first record are used to calculate various intermediate and auxiliary terms such as the daily terrestrial radiation, vapor pressure, long-wave radiation etc. leading finally to a determination of potential evapotranspiration from eq.(2), and, for convenience, is given the name *PM$_{ref}$*.

The one-input *Table* utility is now applied to the Rec and PM$_{ref}$ columns in Table 1, and the *Rec* cell with value 2 is assigned as the utility's *Column Input Cell*. The statement *=PMref* s entered into the first record of *db* in the PM$_{ref}$ output field cell to the right of the *Rec= 2* cell. As with a *Copy* command the potential evapotranspiration is then immediately propagated downward in the PM$_{ref}$ output column, but the difference between the two methods is significant. Specifically, changes can be made in the *PM$_{ref}$* calculation, logical expressions included to account for missing data, modules added, and other generalizations may be introduced in the one PMref calculation in the calculator sheet without requiring any change in the *PMref* output column in Table 1.

Two-Input What-If Table

Another advantage of the *one-Input table* utility is that with little effort one can easily employ Excel's *two-input* option. This is particularly convenient in order to examine the sensitivity of PM$_{ref}$, for example, to some of the inputs in the existing database. If for example, the effect of a change in maximum temperature Tx on the PM$_{ref}$ is of interest, then the Tx

input in the calculator sheet could be generalized to $=Index(db,Rec,1)+ T_{inc}$ where the name T_{inc} is assigned to a cell location with a value of zero. By assigning this cell as the *Row-Input Cell* of a two-input table, the output as illustrated in Table 3 and Table 4 can easily be obtained. In these tables, actual and relative differences from the *Tinc=0* case are calculated as differences from the PM_{ref} output in Table 1, using the output expressions *=PMref-index(db,Rec,10)* and *=(PMref-Index(db,Rec,10)/7)/Index(db,Rec10),* respectively. The essential difference between the two-input tables versus the one-input table is that the output expressions in the former appear in the upper left corner at the intersection of the rows or headings with input values T_{inc} = -7°C, -5°C etc. as deviations from the Tx values associated with *Rec*=2,3,4, etc. pointers; for the one-input table, however, the output expression appears as a sample associated with the first set of input data corresponding to the index counter value *Rec*=2.

Tables 3 and 4 use actual data from Israel; thus they provide insight into the response of potential evapotranspiration to changes in mid-day temperatures. In the broad sense Table 3 indicates that the evapotranspiration response to Tx is higher in summer than in winter; the fractional response indicated in Table 4, on the other hand, is higher in winter than in summer.

Pivot Tables

Basic Pivot Tables

A rainfall database given in Table 5 is used to create a simple pivot table given in Table 6. In this example, the database consists of daily rainfall from 2 regions RegA and RegB, each with 3 stations StnA, StnB and StnC. Essentially, the pivot table is a simple and convenient way of organizing the data in a convenient report form, without requiring any programming experience, and includes useful totals and subtotals. Furthermore, the user may select eight report styles, apart from the displayed default standard, and the orientation may be easily changed whereby the stations and dates in this example, which are displayed in columns and rows respectively, may be reversed.

Pivot tables include a standard *Page field* option, illustrated in Table 7. For example, the region RegB rainfall data are displayed in this design by selecting this region from the RegA and RegB choices within a pick-list box above the pivot table. The *Page field* option, which is in a convenient drop down box allows the user to focus on regions individually.

Stn	Date	*	-7	-5	-3	-1	1	3	5	7
StnA	2001-01-11	2	-0.3	-0.2	-0.1	0.0	0.0	0.2	0.3	0.4
StnA	2001-01-12	3	-0.3	-0.3	-0.2	-0.1	0.1	0.2	0.3	0.4
StnA	2001-01-13	4	-0.5	-0.4	-0.2	-0.1	0.1	0.3	0.5	0.7
StnA	2001-01-14	5	-0.9	-0.7	-0.4	-0.1	0.1	0.5	0.8	1.1
StnA	2001-01-15	6	-0.9	-0.7	-0.4	-0.1	0.2	0.5	0.8	1.2
						.				
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StnA	2001-06-21	10	-1.2	-0.9	-0.6	-0.2	0.2	0.6	1.0	1.5
StnA	2001-06-22	11	-1.3	-0.9	-0.6	-0.2	0.2	0.6	1.1	1.5
StnA	2001-06-23	12	-1.2	-0.9	-0.6	-0.2	0.2	0.6	1.0	1.5
StnA	2001-06-24	13	-1.1	-0.8	-0.5	-0.2	0.2	0.5	0.9	1.3
StnA	2001-06-25	14	-1.4	-1.0	-0.6	-0.2	0.2	0.7	1.2	1.7
						.				
						.				
						.				
StnB	2001-01-11	18	-0.3	-0.2	-0.1	0.0	0.0	0.1	0.2	0.3
StnB	2001-01-12	19	-0.3	-0.2	-0.1	0.0	0.0	0.1	0.2	0.3
StnB	2001-01-13	20	-0.4	-0.3	-0.2	-0.1	0.1	0.2	0.3	0.5
StnB	2001-01-14	21	-0.4	-0.3	-0.2	-0.1	0.1	0.2	0.3	0.5
StnB	2001-01-15	22	-0.5	-0.4	-0.2	-0.1	0.1	0.3	0.5	0.7
StnB	2001-01-16	23	-0.3	-0.2	-0.2	-0.1	0.1	0.2	0.3	0.4

Table 3: Sensitivity analysis based on 2-input what-if table describing changes (mm/day) of PM_{ref} **to changes in daily maximum temperature -7, -5, -3°C, etc.**
$* = PM_{ref} - INDEX(PM_{out}, Rec)$

Stn	Date	*	-7	-5	-1	1	3	5	7
StnA	2001-01-11	2	-20	-15	-3	3	10	18	26
StnA	2001-01-12	3	-21	-16	-3	3	11	19	27
StnA	2001-01-13	4	-22	-17	-4	4	11	20	29
StnA	2001-01-14	5	-22	-17	-4	4	12	20	29
StnA	2001-01-15	6	-22	-16	-3	4	11	19	28
				.					
				.					
				.					
StnA	2001-06-21	10	-14	-10	-2	2	7	11	16
StnA	2001-06-22	11	-15	-11	-2	2	7	12	18
StnA	2001-06-23	12	-16	-11	-2	2	8	13	19
StnA	2001-06-24	13	-15	-11	-2	2	7	12	18
StnA	2001-06-25	14	-17	-12	-3	3	8	14	20
				.					
				.					
				.					
StnB	2001-01-11	18	-19	-14	-3	3	10	16	24
StnB	2001-01-12	19	-19	-14	-3	3	9	16	23
StnB	2001-01-13	20	-21	-16	-3	3	11	18	26
StnB	2001-01-14	21	-20	-15	-3	3	10	17	25
StnB	2001-01-15	22	-21	-16	-3	3	11	18	27
StnB	2001-01-16	23	-20	-15	-3	3	10	17	25

Table 4: Sensitivity analysis based on 2-input what-if table describing fractional changes (%) of PM_{ref} to changes in daily maximum temperature -7, -5, -3°C etc.

$* = (PM_{ref} - INDEX(PM_{out}, Rec)) / INDEX(PM_{out}, Rec)$

Region	Station	Date	Rain
RegA	StnA	1/03/01	0
RegA	StnA	2/03/01	0
RegA	StnA	3/03/01	98.8
RegA	StnA	4/03/01	92.3
RegA	StnA	5/03/01	6.1
RegA	StnA	6/03/01	0
RegA	StnA	7/03/01	0
RegA	StnA	8/03/01	0
RegA	StnA	9/03/01	0
RegA	StnA	10/03/01	0
RegA	StnB	1/03/01	0
RegA	StnB	2/03/01	65.5
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RegB	StnC	4/03/01	49.3
RegB	StnC	5/03/01	0
RegB	StnC	6/03/01	0
RegB	StnC	7/03/01	0
RegB	StnC	8/03/01	32.4
RegB	StnC	9/03/01	0
RegB	StnC	10/03/01	0

Table 5: Sample database for pivot table analysis.

Furthermore, the *Page field* option adds flexibility and prevents the table from growing too large when the user adds more stations and regions into the database.

Another standard pivot table design option which is particularly useful is a grouping option which allows the user to group field items, and includes a special feature which allows users to group time and date fields by regular intervals such as hours, days, months and years. Non-standard time intervals may also be grouped as illustrated in Table 8 in which the rainfall data are grouped into 5-day intervals.

Date	RegA			Total	RegB			Total
	StnA	StnB	StnC		StnA	StnB	StnC	
1/3/01	0	0	46	46	0	0	0	0
2/3/01	0	66	0	66	0	97	58	155
3/3/01	99	0	0	99	0	0	0	0
4/3/01	92	0	0	92	0	0	49	49
5/3/01	6	0	91	97	13	89	0	102
6/3/01	0	0	0	0	56	0	0	56
7/3/01	0	0	0	0	0	0	0	0
8/3/01	0	93	0	93	0	0	32	32
9/3/01	0	0	0	0	100	0	0	100
10/3/01	0	0	0	0	0	53	0	53
Total	197	158	136	492	169	239	140	547

Table 6: Simple pivot table associated with database in Table 5.

Pivot Tables were generally designed for financial applications, which usually involve the *Sum* function. The same principles, however, apply to other statistical functions to calculate maxima, as illustrated in Table 8, minima, means and standard deviations, and are of obvious importance in agrometeorological applications. This includes the *Count* function, which is particularly useful because it retrieves the size of the data sample associated with the statistical operations. The use of this feature will be illustrated in the following discussion, which describes two advanced features – the *GetPivotData* and *Difference* functions.

Advanced Pivot Tables

Table 9 is a sample database similar to in structure to the database samples in Table1 and Table 5, except for a simple addition. Specifically, two additional fields are added – a Cum field to designate seasonal accumulation of rainfall from a specified date until Oct. 10 in the example, and a Base field which contains long-term data and situated for convenience at the top of the database. The associated pivot table in Table 10 contains in the example differences of average maximum temperature in the October 11-20, 2001 dekad period and percent differences of rainfall, both seasonally

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Region	RegB ⇓			
Date	StnA	StnB	StnC	Total
1/03/01	0	0	0	0
2/03/01	0	97	58	155
3/03/01	0	0	0	0
4/03/01	0	0	49	49
5/03/01	13	89	0	102
6/03/01	56	0	0	56
7/03/01	0	0	0	0
8/03/01	0	0	32	32
9/03/01	100	0	0	100
10/03/01	0	53	0	53
Total	169	239	140	547

Table 7: Sample use of Page field associated with database in Table 5.

and for the dekad. This advanced feature extends the use of statistical operators by relating them to base fields and items, and is particularly useful on agrometeorological applications.

Perhaps one of the most important and useful pivot table utilities is the *GetPivotTable* function. It is included within the *lookup and reference* function category, and consists of two arguments or inputs. The first argument identifies or references the pivot table itself or any part thereof; the second argument is a string expression, (or equivalently, cell references which concatenate to a text expression) associated with one of the values in the pivot table. For example, =*GetPivotData (PT, "StnA TDXavg Dekad 2001")* retrieves the average maximum temperature of the Dekad (as opposed to the Normal) for the year 2001, assuming the entire pivot table or an arbitrary cell within is assigned for convenience the name *PT*.

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	Date	RegA			Total	RegB		
		StnA	**StnB**	**StnC**		**StnA**	**StnB**	**StnC**
Sum	1/3/01-5/3/01	197	66	136	399	13	186	108
	6/3/01-10/3/01	0	93	0	93	156	53	32
Max	1/3/01-5/3/01	99	66	91	99	13	97	58
	6/3/01-10/3/01	0	93	0	93	100	53	32
Total Sum		197	158	136	492	169	239	140
Total Max		99	93	91	99	100	97	58

Table 8: Sample grouping of date field into 5-day periods for pivot table associated with pivot table in Table 5.

The usefulness of this feature can hardly be overestimated as it allows the user to access specific information using simple text expressions. Furthermore, it allows the user to design a dedicated report form in which data entries in its cells would access select pivot table values of interest. This is particularly important because the standard pivot table layout options are only suitable for financial reports and often contain redundant information.

Another important advantage of the *GetPivotData* function is that it allows the user to select information selectively from a pivot table based on logical criteria considerations. For example, it can easily be combined with the logical *If* statement to conditionally account for partially missing data in the database. Referring to the pivot table in Table 10 as an example, an expression in a report summarizing average of maximum temperatures in a report may be inserted as follows:

=If(GETPIVOTDATA(PT,"StnA TDXobs Dekad 2001" >6,

GetTPIVOTDATA(PT,"StnA TDXavg Dekad 2001",”-”)

where TDXobs refers to the use of the *Count* function to retrieve the sample size.

This expression therefore would enter into a report the average of maximum temperatures of StnA for the specific 10-day period only if there are at least 7 observations in the database. Thus, the *GetPivotData*

Cum	Base	Stn	Date	RN	TDx	TDn
	Normal	StnA	2001-10-20	10	17.0	4.5
	Normal	StnB	2001-10-20	10	18.0	5.5
Season	Normal	StnA	2001-10-10	90		
Season	Normal	StnB	2001-10-10	190		
Season		StnA	2001-10-10	99		
Season		StnB	2001-10-10	93		
		StnA	2001-10-11	0	10.0	3.7
		StnA	2001-10-12	0	11.2	4.4
		StnA	2001-10-13	0	12.3	5.4
		StnA	2001-10-14	5	12.2	5.4
		StnA	2001-10-15	6	9.9	5.3
		StnA	2001-10-16	0	9.8	4.2
		StnA	2001-10-17	0	10.0	4.0
		StnA	2001-10-18	0	10.0	5.0
		StnA	2001-10-19	0	11.1	5.0
		StnA	2001-10-20	0	11.1	5.0
		StnB	2001-10-11	0	12.0	2.2
			.			
			.			
			.			
		StnB	2001-10-15	3	12.0	2.0
		StnB	2001-10-16	0	22	8.1
		StnB	2001-10-17	0	21	7.9

Field symbols: RN rainfall (mm); TD_x and TD_n maximum and minimum temperatures (^{o}C).

**Table 9: Sample database to illustrate incorporating seasonal totals
and comparisons with normals in pivot tables.**

Cum	Data	Base	Stn
		2001	
		StnA	StnB
Season	RAIN	99	93
	RAIN_Dif %	10%	-51%
	TDXmax		
	TDXavg		
	TDXavg_Dif	0.0	0.0
	TDXobs		
Dekad	RAIN	11	12
	RAIN_Dif %	10%	20%
	TDXmax	12.3	22
	TDXavg	10.8	14.7
	TDXavg_Dif	-6.2	-3.3
	TDXobs	10	7
Total RAIN		110	105
Total RAIN_Dif%		10%	-48%

Field and operator symbols: TDX maximum temperature (oC);
Dif and Dif% actual (mm or oC) and fractional differences (%);
Obs Sample size.

Table 10: Pivot table associated with database in Table 9.

effectively transforms the pivot table, from one that organizes and statistically summarizes a database, to a system of pointers which links the database and the statistics to a suitably designed and dedicated agrometeorological report. The latter then functions as a template, which updates the report using a simple *Refresh* command to reflect changes in the original database. It should be noted furthermore, that the Excel 2000 includes a useful chart module linked to pivot tables which simplifies and conveniently links various graphing options.

Conclusions

Two Excel utilities, what-if input tables and pivot tables, were examined as potential tools for processing and design of reports using agrometeorological data.

It has been demonstrated that these modules may be adapted to enhance both routine and operational agrometeorological practices. Both modules, which are linked to databases, do not require any programming experience and yet may be easily adapted as dedicated utilities in agrometeorology. It is of interest therefore to monitor developments and improvements in input and pivot tables, which generally parallel improvements in low-cost computer power.

References

Allen, R., Pereira, L.A., Raes, D. and M. Smith. 1998. Crop Evapotranspiration. FAO Irrigation and Drainage Paper No. 56. Rome.

Jensen, M.E., Burman, R.D. and R.G. Allen. 1990. Evapotranspiration and Irrigation Water Requirements. ASCE manuals and Reports on Engineering Practice No. 70.

Penman, H.L. 1948. Natural evaporation from open water, bare soil and grass in *Proceedings of the Royal Society A,* 193: 120-145.