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# Pan Coefficients Using Penman Approach with Different Vapor Pressure Deficits

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ABSTRACT. Daily lake evaporation at Malham and Al-Amalih reservoirs (Central Saudi Arabia) was determined using Penman's equation with different methods of calculating vapor pressure deficit. The variability of annual, monthly and seasonal pan coefficients at the two sites was investigated. Available data for a three-year period was utilized in the study. Results showed that the proposed model gave reasonable predictions of annual lake evaporation and pan coefficients. The predictions were best with the first method of computing vapor pressure deficit. The model gave similar trends when applied to other stations in the region. However, the results were not as good as at Malham and Al-Amalih reservoirs sites. Monthly pan coefficients showed lower values during summer months than for the rest of the year which is consistent with physical reality. Estimates of both monthly and seasonal pan coefficients were reasonable for Malham and Al-Amalih sites.

## Introduction

Estimation of free-water surface evaporation is essential in many engineering and hydrological applications such as planning, design, operation and management of lakes and reservoirs. Evaporation is also an indispensable parameter in many hydrological models. Evaporation can be defined as the net rate of vapor transport to the atmosphere. It raises the storage requirements of reservoirs and lowers the yield of lakes and ponds, swamps and other wet surfaces and return much water to the atmosphere.

While actual evaporation is hard to measure directly from an open water surface, there are many approaches used to estimate evaporation such as water and energy budgets, aerodynamic and combination methods. Penman approach is one of the most famous methods which is derived from the above methods. Although it requires many parameters for its use, many of the climatological variables used in the Penman approach are usually available. Penman's equation combines an energy balance and an aerodynamic term. The aerodynamic portion of the equation contains a measure of vapor pressure deficit. There are several methods of computing vapor pressure deficit available in literature. These methods can basically be divided into temperature averaging or pressure averaging methods.

The major objective of this study is to investigate the variability of annual, monthly and seasonal pan-to-lake coefficient at two sites in Central Saudi Arabia. To achieve this objective, daily lake evaporation using Penman approach utilizing available climatological data at the two sites were calculated. These sites are site 1 (Malham) and site 2 (Al-Amalih). Different methods of computing vapor pressure deficit were used. Data for Malham and Al-Amalih sites are daily data for three years taken from two meteorological stations that are located near the dams at the two sites. They include temperature, relative humidity, wind speed, solar radiation, and pan evaporation.

## Background

Rates of evaporation from a free-water surface vary depending on meteorological factors (Linsley *et al.*, 1982). The rate of evaporation is influenced by solar radiation, air temperature, vapor pressure, wind and minimally by atmospheric pressure. Since solar radiation is an important factor, evaporation varies with latitude, season, time of day, and sky conditions. The rate of evaporation is also proportional to wind speed and highly dependent on the vapor pressure.

Methods of estimating evaporation from open water surfaces include water budget methods, energy budget methods, aerodynamic approaches, combination methods such as Penman approach and evaporation Pan readings multiplied by certain coefficients (Linsley *et al.*, 1982).

The water budget approach is simple in theory, but application rarely produces reliable results since all errors in measuring precipitation, inflow, outflow and change in storage are reflected directly in the computed evaporation (Linsley *et al.*, 1982). It is applicable to well controlled inflow, outflow and storage change measurement at lake from which seepage losses are known to be small (Doorenbos and Pruitt, 1981).

The energy-budget approach, like the water-budget, employs a continuity equation and solves for evaporation as the residual required to maintain balance. Although the continuity equation in this case is one of energy, an approximate water budget is required as well, since inflow, outflow, and storage of water represent energy values which must be considered in conjunction with the respective temperatures.

Numerous empirical formulas have been derived using aerodynamic approaches. They express evaporation as a function of atmospheric elements and they parallel the turbulent-transport approaches in some respects. An example of aerodynamic equations is the Meyer's formula (El-Sarami, 1989). For its application, it requires an empirical coefficient (suitable for a certain location) and the wind speed in miles per hour at 25 ft. above the water surface.

Evaporation may be computed by an aerodynamic method if energy supply is not limiting and by the energy balance method if vapor transport is not limiting. But, normally, both of these factors are limiting, so a combination of the two methods is needed. In the energy balance method, the sensible heat flux is difficult to quantify. But since the heat is transferred by convection through the air overlying the water surface, and water vapor is similarly transferred by convection, it can be assumed that the vapor heat flux and the sensible heat flux are proportional, the proportionality constant being called the Bowen ratio (Chow *et al.*, 1988). By assuming a free-water surface, Penman (1948) derived his famous equation which is a combination of an energy-budget and an aerodynamic approach. Penman method of calculating evaporation rates from meteorological data is the most accurate method when all the required data are available and the assumptions are satisfied. The chief assumptions of the energy balance are that steady state energy flow prevails and that changes in heat storage over time in the water body are not significant. This assumption limits the application of the method of daily time intervals or longer, and to situations not involving large heat storage capacity, such as a large lake possesses. Thus the method is well suited for application to small water surfaces (reservoirs) on daily basis (or longer) if detailed climatological data is available.

Evaporation pans are the most commonly used instruments to measure evaporation, and are often considered a direct measurement. Use of land based pans for lake studies has a major disadvantage that has received a great deal of attention, that is, relating pan evaporation to lake evaporation. Obviously, lakes have considerably different wind and thermal regimes than pans located on land. Development of the floating pan was designed to at least partly overcome this disadvantage. Winter (1981) reviewed evaporation pan designs, pan positions, and relationship of pan evaporation to lake evaporation.

In addition to the problem of designing the ultimate evaporation pan, an even more perplexing problem is the relationship of pan evaporation to lake evaporation (pan coefficients). A basic requirement in developing pan to lake coefficients is that lake evaporation is known. Water-budget, energy-budget, and aerodynamic techniques can be used to estimate evaporation from existing reservoirs and lakes. However, these methods are not directly applicable to design problems, since water-temperature observations are required in their use. The combination methods are beginning to come into use, but estimates of reservoir evaporation, both for design and operation, have been traditionally made by applying a pan coefficient. Although too few determinations have been made to appraise the approach accurately, assuming an annual Class A pan coefficient of 0.70 for the lakes would result in a maximum difference of 15 percent. Part-year coefficients are more variable because energy storage on the lake can be appreciably different at the beginning and end of the period and changes in heat storage cause pronounced variations in monthly coefficients which must be taken into account (Linsley *et al.*, 1982). The coefficients normally increase for smaller water bodies and decrease for arid regions as opposed to humid regions (Warnaka, 1985).

## Study Sites

The two major study sites chosen for this study are Malham and Al-Amalih reservoirs; both located in Central Saudi Arabia. The sites are located 75 km and 175 km northwest of Riyadh (see Fig. 1). The region has arid climatic characteristics with an average annual rainfall of 115 mm.

Malham is a rockfill dam located at the intersection of 25°08′N latitude and 46°14′E longitude. It drains a catchment of about 289 $km^2$ and it has a storage capacity of 0.5 million $m^3$. Malham dam was completed in 1970 and the silt deposits on the reservoir bed ranged from 30 cm up to 120 cm with the amount increasing closer to the dam axis. Al-Amalih is a concrete dam located at about 25°35′N latitude and 45°35′E longitude. Its storage capacity is 1.0 million $m^3$ with a catchment area of 21.6 $km^2$. It was completed in 1982 and the amount of silt deposits ranged between 0 and 30 cm at the beginning of the study.

A meteorological station is availabe at each site. Each station includes a recording rain gauge, class A pan, an actinograph, a wind recorder, a thermometer shelter with its standard equipment, an evaporation balance and a standard rain gauge.

## Description of the Model

The model used in this study is based on Penman method (1948, 1963) because it is one of the most accurate methods used in calculating daily evaporation rates. Penman's equation separates the effects of solar energy input and advection by dividing evaporation into an energy balance component and an aerodynamic component. The aerodynamic component itself has two terms. The first is a wind term which is a function of wind velocity. This is multiplied by a second term which is the difference between saturated vapor pressure and ambient vapor pressure (vapor pressure deficit). There are several methods for computing vapor pressure deficit, and each yields a different quantity. Uncertainties and errors have risen in the application of Penman's equation because of misconceptions in the calculation of the vapor pressure deficit.

Penman's equation in this study was used in the following form :

$$E = \frac{\Delta}{\Delta + \gamma} R_n + \frac{\gamma}{\upsilon + \Delta} E_a \tag{1}$$

where $E$ is the evaporation rate, in mm/day, $\gamma$ is the psychrometric constant in (mb/°C), $\Delta$ is the slope of the saturation vapor pressure versus temperature curve at the mean air temperature in (mb/°C), $R_n$ is the net radiation energy at the water surface ($cal/cm^2/day$) and $E_a$ is the aerodynamic term (mm/day).

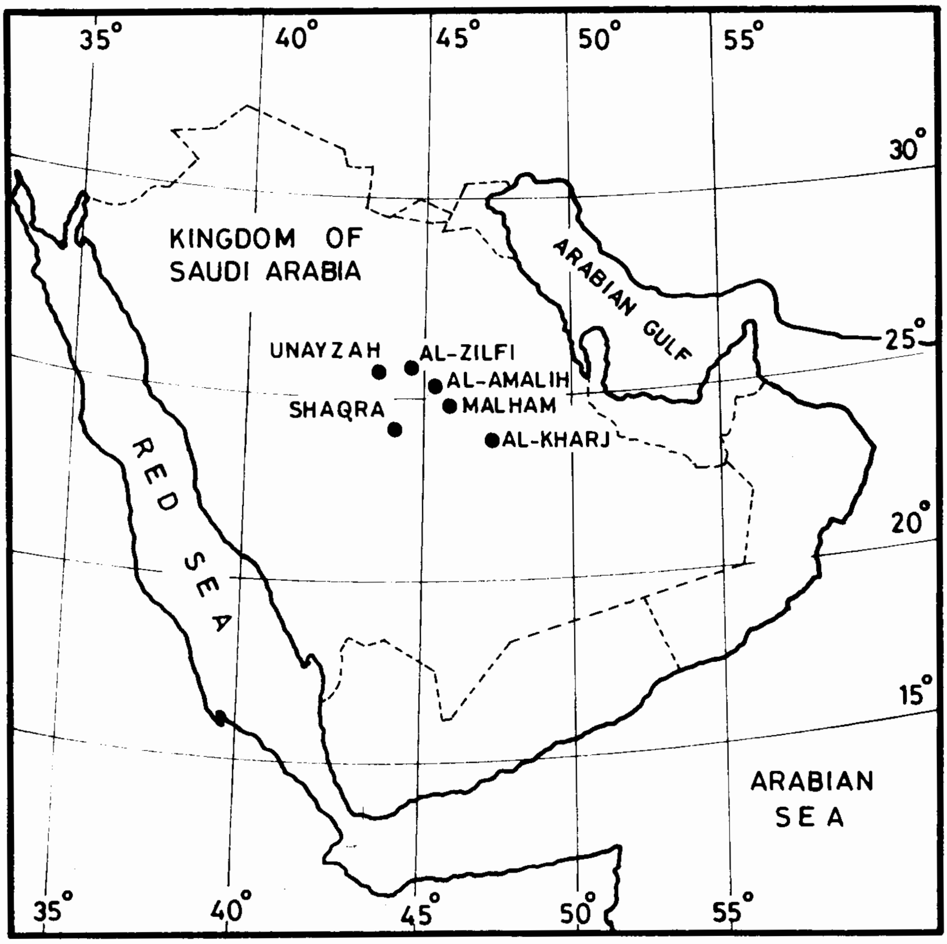


FIG. 1. Location of study sites.

Terms in equation (1) were calculated as follows :

$$\frac{\Delta}{\Delta + \gamma} = \left[ 1 + \frac{.66}{(.00815\ T_a + .8912)^7} \right]^{-1} \tag{2}$$

$$T_a \geq -25°C$$

$$\text{where } T_a = \frac{T_{max} + T_{min}}{2} \tag{3}$$

where $T_a$ is the average air temperature in degrees celsius, $T_{max}$ is the maximum air temperature in degrees celsius and $T_{min}$ is the minimum air temperature in degrees celsius.

The other dimensionless ratio is computed from the following expression :

$$\frac{\gamma}{\gamma + \Delta} = 1 - \frac{\Delta}{\Delta + \gamma} \tag{4}$$

The net radiation $R_n$ was expressed in the model by the following expression :

$$R_n = (1 - \alpha) \; R_s - R_b \tag{5}$$

where $\alpha$ is the reflected short wave radiation, $R_s$ is the incoming short wave solar radiation (This variable is normally measured by radiometer) and $R_b$ is the net outgoing long wave radiation and was calculated by :

$$R_b = \left[ a \frac{R_s}{R_{so}} + b \right] R_{bo} \tag{6}$$

where $R_{so}$ is the clear day solar radiation (cal/cm$^2$/day) obtained from mean daily solar radiation table for cloudless skies, $R_{bo}$ is the net outgoing long wave radiation on a clear day and it is calculated by the following expression :

$$R_{bo} = (a_1 + b_1 \sqrt{e_a}) \; 11.71 \times 10^{-8} \; T_k^4 \tag{7}$$

where $T_k$ is the average daily air temperature in °$K$, $e_a$ is the saturation vapor pressure at the mean daily dew point and it is equal to :

$$e_a = e_s \times RH \tag{8}$$

where $RH$ is the relative humidity and $e_s$ is the saturation vapor pressure at the mean air temperature and is calculated by :

$$e_s = 33.86 \, [(.00738 T_a + .8072)^8 - .000019 \, (1.8 T_a + 48) + .001316] \tag{9}$$

The constants in equations (6) and (7); $a$, $b$, $a_1$ and $b_1$ were taken as representative values for arid climate 1.2, – 0.2, 0.39 and – 0.05 respectively (Jensen, 1980).

Since the calculation of evaporation are normally required in mm/day, $R_n$ has to be converted from cal/cm$^2$/day to mm/day. This is done by dividing $R_n$ by the latent heat of vaporization which is given by the following equation (Jensen, 1980).

$$H_v = 595 - (.51) \; T_a \tag{10}$$

where $H_v$ is the latest heat of vaporization (cal/g) and $T_a$ is the average air temperature (°C).

For the calculation of $E_a$ in equation (1), an equation suggested by Stiger (1980) which is suitable for Penman's equation was used. It is given as follows :

$$E_a = .26 \, (.5 + .54 \; U_2) \; (d_e) \tag{11}$$

where $U_2$ is the wind speed at 2 m above ground in (m/s) and $d_e$ is the vapor pressure deficit (mb).

There are six methods for computing the vapor pressure deficit, and each yield a different quantity (Cuenca and Nicholson, 1982).

These methods can basically be divided into temperature averaging or pressure averaging methods. In temperature averaging methods, the saturated vapour pressure and ambient or dew point vapor pressure are computed based on an average temperature. In vapor pressure averaging methods, a method is used to compute the saturation deficit at various times during a day and the average of these values is used. The six methods that were considered in this study were (Cuenca and Nicholson, 1982) :

$$1.\ d_e = (e_s)_{ave} - (e_{dp})_{min} \tag{12}$$

$$2.\ d_e = (e_s)_{ave} - (e_{dp})_{ave} \tag{13}$$

$$3.\ d_e = (e_s)_{ave} - RH_{ave}\ (e_s)_{ave} \tag{14}$$

$$4.\ d_e = \frac{(e_s)_{max} + (e_s)_{min}}{2}\ (e_{dp})_{ave} \tag{15}$$

$$5.\ d_e = \frac{[(e_s)_{max} - e_{max}] + [(e_s)_{min} - e_{min}]}{2} \tag{16}$$

$$6.\ d_e = (e_s)_{ave} - e_{air} \tag{17}$$

where $(e_s)_{ave}$ is the saturation vapor pressure at average air temperature, $(e_s)_{max}$ is the saturation vapor pressure at maximum air temperature, $(e_s)_{min}$ is the saturation vapor pressure at minimum air temperature, $e_{max}$ is the saturation vapor pressure at maximum daily dewpoint, $e_{min}$ is the saturation vapor pressure at minimum daily dewpoint, $(e_{dp})_{ave}$ is the vapor pressure at average dewpoint temperature, $(e_{dp})_{min}$ is the vapor pressure at minimum dewpoint temperature, $RH_{ave}$ is the average relative humidity and $e_{air}$ is the actual vapor pressure.

Methods 1, 2 and 3 represent temperature averaging methods, while 4 and 5 are vapor pressure averaging methods. Method 6 does not fit directly into either category, but results in computed values close to those from the temperature averaging methods. Methods 1, 3, 4, 5 (M1, M3, M4, M5) were used in this work, but methods 2 (M2) and 6 (M6) were not used because M2 gives results that are the same as M3 and M6 requires the use of wet bulb depression which cannot be calculated due to unavailability of wet bulb temperatures.

A simple computer program was written and used to carry out all the necessary calculations. The program which is in Pascal language starts with reading of input data which consists of maximum and minimum temperature, relative humidity, incoming short wave radiation, clearday solar radiation, wind speed and class (A) pan evaporation. Daily values were available for sites 1 and 2 for a period of three years. The results obtained through the application of this program include daily lake evaporation, monthly and annual evaporation at the two sites. It also include daily, monthly, annual and averages of monthly and annual pan coefficient.

## Results and Discussion

### *Daily and Annual Evaporation*

The first task in this study was to predict daily lake evaporation at Malham and Al-

Amalih sites (1 and 2 respectively) using the suggested model. Daily values of temperature, relative humidity, solar radiation and wind speed that are available for three years at Malham and Al-Amalih were used in the computer program. The purpose was to calculate daily lake evaporation at the two sites using Penman approach with the different methods of expressing vapor pressure deficit M1, M3, M4 and M5. The range of the daily evaporation was between 0.46 mm/day to 13.02 mm/day while daily pan coefficients ranged between 0.22 and 1.67.

To obtain the annual lake evaporation for the three years at the two sites, daily lake evaporations for each year were added. Tables 1 and 2 give the predicted annual lake evaporation, annual pan evaporation as measured using Class A pans that were installed at the sites and the annual pan coefficients as calculated by the model.

TABLE 1. Annual evaporation and pan coefficients for Site 1 (Malham).

| Year | Pan Evap. (mm) | M1 | | M3 | | M4 | | M5 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Evap. (mm) | Coef. | Evap. (mm) | Coef. | Evap. (mm) | Coef. | Evap. (mm) | Coef. |
| 1 | 3995 | 2371 | .59 | 2184 | .55 | 2286 | .57 | 2249 | .56 |
| 2 | 4288 | 2441 | .57 | 2264 | .53 | 2377 | .55 | 2338 | .55 |
| 3 | 4242 | 2534 | .60 | 2355 | .56 | 2463 | .58 | 2426 | .57 |
| Ave. | 4175 | 2449 | .59 | 2268 | .54 | 2375 | .57 | 2338 | .56 |

TABLE 2. Annual evaporation and pan coefficients for Site 2 (Al-Amalih ).

| Year | Pan Evap. (mm) | M1 | | M3 | | M4 | | M5 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Evap. (mm) | Coef. | Evap. (mm) | Coef. | Evap. (mm) | Coef. | Evap. (mm) | Coef. |
| 1 | 4229 | 2380 | .56 | 2174 | .51 | 2288 | .54 | 2246 | .53 |
| 2 | 4428 | 2536 | .57 | 2327 | .53 | 2446 | .55 | 2402 | .55 |
| 3 | 4354 | 2609 | .60 | 2404 | .55 | 2524 | .58 | 2482 | .57 |
| Ave. | 4337 | 2508 | .58 | 2302 | .53 | 2419 | .56 | 2377 | .55 |

The results in these tables show that the model with the method M1 gave the highest annual pan coefficients with averages of 0.59 and 0.58 for sites 1 and 2 respectively. This is followed by M4 (0.57 and 0.56), then M5 (0.56 and 0.55) and the lowest values of 0.54 and 0.53 were given when M3 was used. The results show consistency between the methods in predicting the three years' results.

The annual pan coefficient (as an average value) is thought to be 0.7. If this is accepted to be true everywhere, then all the methods used in this study in calculating vapor pressure deficit have underestimated annual pan coefficients with M1 of course giving the closes values. However, it seems that for certain arid regions, the value of the annual pan coefficient can be as low as 0.64 or 0.65 (Linsley *et al.*, 1982). Assuming a value of 0.65, the deviations between the predictions of the model and the observed class A pan values ($E_{clap}$) multiplied by 0.65 were calculated and they are shown in Tables 3 and 4.

TABLE 3. Deviations between predicted annual lake evaporation (mm) and pan evaporation (mm) × 0.65 for Site 1 (Malham).

| Years / Evaporation method | Year 1 | Year 2 | Year 3 | Average evap. and dev. |
|---|---|---|---|---|
| $0.65 \times E_{clap}$ | 2597 | 2787 | 2757 | 2714 |
| M1 | 2371 | 2441 | 2534 | 2449 |
| Deviation % | 8.71 | 12.41 | 8.09 | 9.74 |
| M3 | 2184 | 2264 | 2355 | 2268 |
| Deviation % | 15.90 | 18.77 | 14.58 | 16.42 |
| M4 | 2286 | 2377 | 2463 | 2375 |
| Deviation % | 11.98 | 14.71 | 10.66 | 12.45 |
| M5 | 2249 | 2338 | 2426 | 2338 |
| Deviation % | 13.40 | 16.11 | 12.01 | 13.84 |

It is clear from these two tables that the lowest deviations (as an average) were obtained when M1 was used. For the three years shown, M1 gave average deviations of 9.74% and 11.04% for sites 1 and 2 respectively. This is followed by M4 and M5 with M3 giving the highest deviations of 16.42% and 18.37%. The deviations were also calculated for the case when the annual pan coefficient is assumed to be 0.70 instead of 0.65. Even for that case, the deviations for M1 were between 16 and 17%.

### *Monthly and Seasonal Evaporation*

The value of 0.70 (or a value close to it) may be accepted on an annual basis, but it is not acceptable for monthly or seasonal prediction of evaporation. The main reason is that energy storage can be appreciably different at the beginning and at the end of the period. This will cause variations in monthly coefficients. In this study, the variability of the monthly pan coefficients was investigated. Daily evaporation values as predicted by the model were prepared for each month at sites 1 and 2. The monthly pan coefficients were then calculated by dividing the total monthly evaporation by the observed monthly pan evaporation.

Figures 2 and 3 show the average monthly pan coefficients at the two sites and for the different methods of computing vapor pressure deficit M1, M3, M4 and M5. For both sites, M1 gave higher monthly pan coefficients; ranging from a high of 0.73 for

TABLE 4. Deviations between predicted annual lake evaporation (mm) and pan evaporation (mm) × 0.65 for Site 2 (Al-Amalih).

| Years / Evaporation method | Year 1 | Year 2 | Year 3 | Average evap. and dev. |
|---|---|---|---|---|
| $0.65 \times E_{clap}$ | 2749 | 2878 | 2830 | 2819 |
| M1 | 2380 | 2536 | 2609 | 2508 |
| Deviation % | 13.42 | 11.88 | 7.81 | 11.04 |
| M3 | 2174 | 2327 | 2404 | 2302 |
| Deviation % | 20.92 | 19.14 | 15.05 | 18.37 |
| M4 | 2288 | 2446 | 2524 | 2419 |
| Deviation % | 16.77 | 15.01 | 10.81 | 14.20 |
| M5 | 2246 | 2402 | 2482 | 2377 |
| Deviation % | 18.30 | 16.54 | 12.30 | 15.51 |

TABLE 5. Average seasonal pan coefficients.

| Method | Malham | | Al-Amalih | |
|---|---|---|---|---|
| | May - Oct. | Nov. - Apr. | May - Oct. | Nov. - Apr. |
| M1 | 0.55 | 0.70 | 0.53 | 0.72 |
| M3 | 0.52 | 0.61 | 0.50 | 0.62 |
| M4 | 0.54 | 0.65 | 0.52 | 0.65 |
| M5 | 0.54 | 0.63 | 0.52 | 0.63 |

December to a low of 0.53 for July, August and September at site 1. The monthly pan coefficients as shown in Fig. 2 and 3 show lower values during summer and generally higher values in the other seasons. Higher coefficients are normally observed in fall when the pan is relatively cool while lower values occur in late spring and summer when the pan warms up more rapidly (Linsley and Franzini, 1979).

Table 5 presents the average pan coefficients for the two different seasons; May-October and November-April with the first representing the warm season and the second being the cool season (for Central Saudi Arabia). In some models, it is convenient to have a coefficient for summer and another one for winter.

### *Model Applications to Other Stations*

The model was applied to other stations in Central Saudi Arabia. Data available included average monthly values for most of the meteorological variables needed.

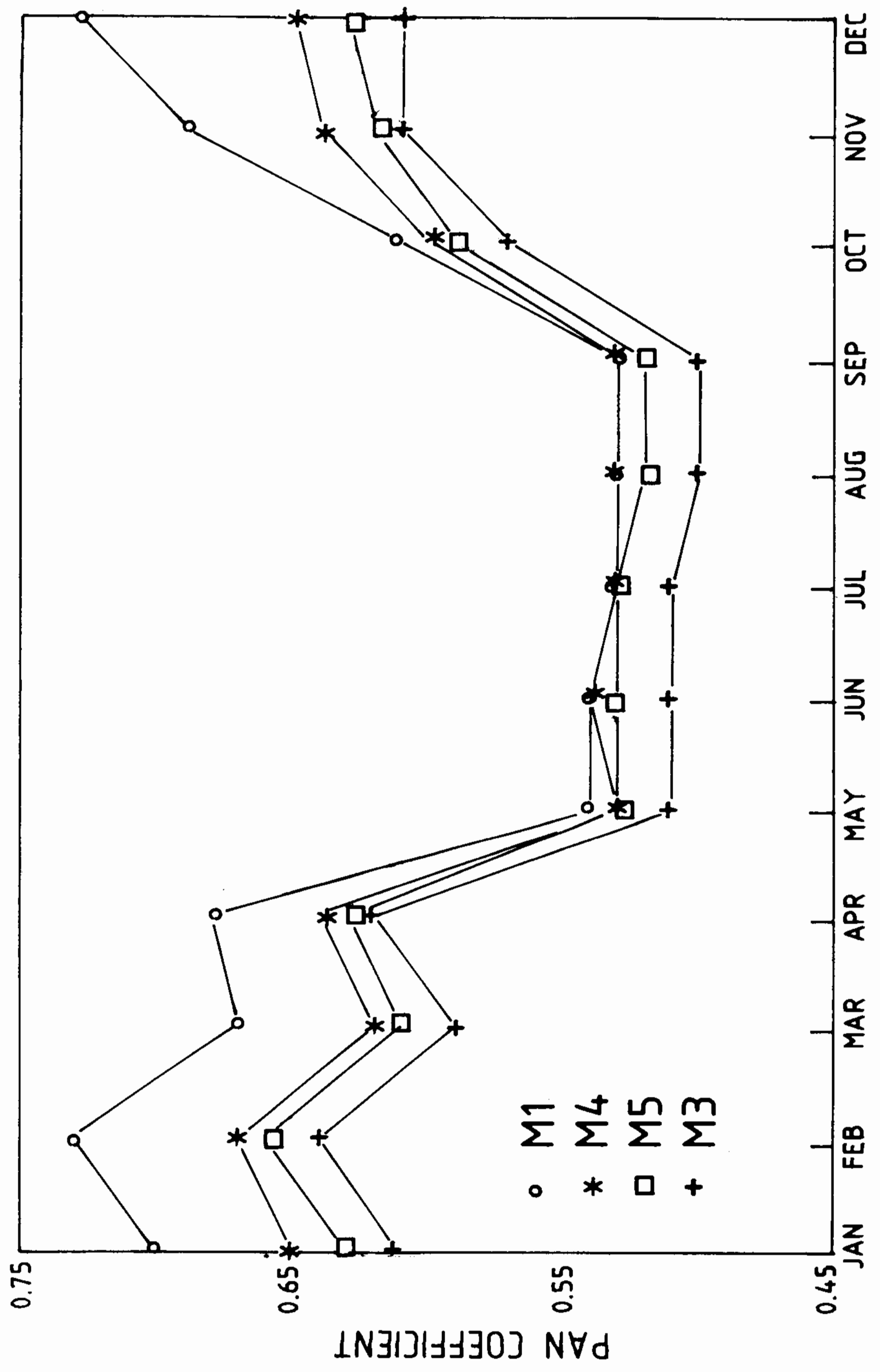


FIG. 2. Average monthly pan coefficients, Malham.

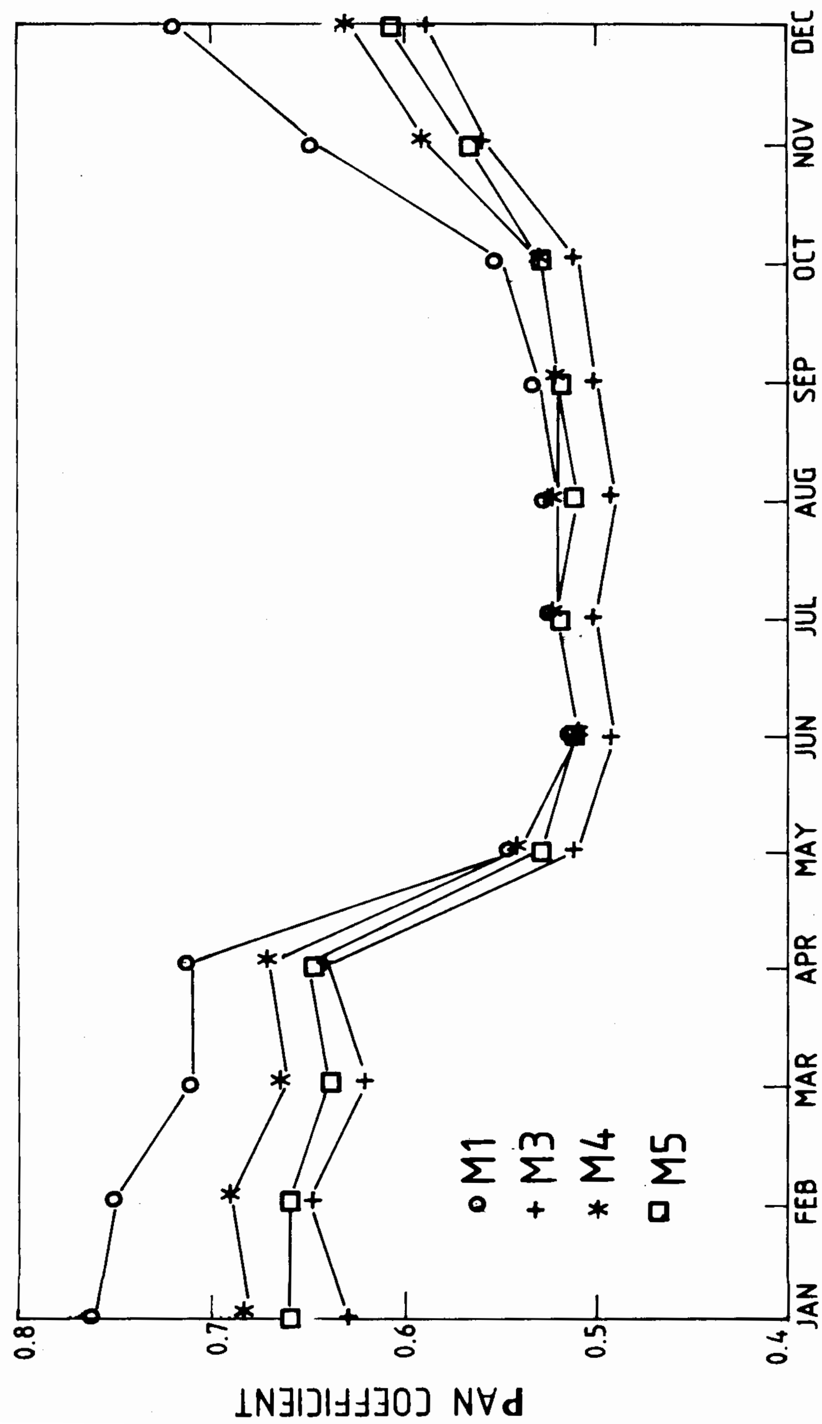


FIG. 3. Average monthly pan coefficients, Al-Amalih.

However, there was a problem related to wind records for some of these stations. The values were too low compared to the recorded ones at Malham (Site 1) and Al-Amalih (Site 2). As an example, the data for Al-Kharj and Al-Zilfi were tried because of the completeness of the records for a number of years. The results , however, were completely unacceptable. For almost all the stations, data on temperature, relative humidity and solar radiation were available and they are of good quality. Pan evaporation records, however, were missing for some of the year at some of the stations.

Data form another two stations; Unayzah and Shaqra were also used in the model. The first contained 17 years of records while there were only 8 years of complete records at the second. The results for Unayzah and Shaqra were similar in their trends as the results for sites 1 and 2. However, annual evaporations were lower. For example, Unayzah mean annual pan coefficient was found to be 0.49 for the 17 years of records (using M1) and slightly lower values for the other methods. Monthly values for pan coefficients showed similar trend as before; with lower values in the summer and higher during the rest of the year.

## Conclusion

The Penman's approach was used in this study to calculate evaporation rates at two sites in Central Saudi Arabia. Four different methods of calculating vapor pressure deficit were applied. The results have shown that the presented model has predicted annual evaporation and annual pan coefficients reasonably well. The first method (M1) of calculating vapor pressure deficit gave the closest results when compared to annual pan evaporation multiplied by 0.65 or 0.70. The method M1 is a temperature averaging method of calculating vapor pressure deficit and it is given by equation (12). The variability of monthly and seasonal pan coefficients was also investigated. Results showed lower monthly pan coefficients for the summer months than the rest of the year which is consistent with physical reality. The model was also applied to few other locations in the region. However, the results were not as good as for sites 1 and 2. A more detailed examination of data available at other locations is needed to determine why low values of evaporation were obtained by the model.

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# تقدير معاملات التبخر باستخدام معادلة بنمان مع طرق مختلفة لحساب الفرق في ضغط بخار الماء

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**المستخلص** : في هذا البحث تم حساب التبخر اليومي من حوضي تخزين في ملهم والأمالح بالمنطقة الوسطى من المملكة باستخدام معادلة بنمان مع طرق مختلفة لحساب الفرق في ضغط بخار الماء . كما تمت دراسة تغير معاملات التبخر السنوية والشهرية والفصلية عند هذين الموقعين . وأظهرت النتائج أن النموذج المقترح يعطي تقديرات جيدة للتبخر السنوي ومعاملاته ، وكانت أفضل تقديرات لذلك عند استخدام الطريقة الأولى لحساب الفرق في ضغط بخار الماء . ولقد أظهرت نتائج تطبيق النموذج على مناطق أخرى نفس التوجهات العامة ، ولكن النتائج لم تكن جيدة كما كانت في ملهم والأمالح . كما أظهرت نتائج البحث أن معاملات التبخر خلال أشهر الصيف أقل من بقية السنة ، والذي يتوافق مع الواقع كما أن تقديرات النموذج لمعاملات التبخر الشهرية والفصلية في ملهم والأمالح كانت معقولة .