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A Monthly Six-parameter Water Balance Model and Its Application at Arid and Semiarid Low Yielding Catchments

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Abstract. A monthly six-parameter water balance model is developed. The intended use of this model is to simulate monthly runoff at arid and semiarid low yielding catchments, which at most suffer from drastic lack of hydrological information, and in time when this information is available, it is highly variable in time and space. The proposed model was calibrated and tested using available data collected from two catchments in the Middle East located at Yemen and Jordan. The simulation results obtained show that the model has a good match between the monthly observed and simulated runoff. Application results suggest that the proposed model is theoretically sound and practically simple and efficient for runoff prediction at low yielding catchments. The model will be useful for efficient planning and management of water resources and assessment of climatic change impacts at arid and semiarid regions.

Keywords: Hydrologic modeling, Catchment modeling, Water balance model.

1. Introduction

In many parts of the world rapid population growth, urbanization and industrialization have increased the demand for water. It is becoming increasingly critical to plan, design and manage water resources system carefully and intelligently. Water scarcity is a major constraint to any development in many parts of the world, especially at arid and semiarid regions. Gan *et al.* [1] stated that catchments with streamflow to rainfall ratios of 0.2 or less are generally referred as dry lands. According to a classification proposed by UNESCO [2], the catchments are classified as arid when the ratio of annual rainfall to annual reference evaporation is between 0.03 to 0.25 and as semiarid when this ratio is between 0.25 to 0.5. Water harvesting of runoff and flood water at these catchments can represent an additional water resources of a good quality at a relatively low cost. Improving water harvesting techniques necessitates a more accurate rainfall-runoff relationships.

Rivers in arid and semiarid regions have a number of typical features. In the first place, rivers that are permanent over the entire length of their stream beds are uncommon in arid regions. On the contrary, most of rivers are ephemeral; only a few have minor base flow that may be seasonal or even permanent, but only in a limited part of their channel network. Typically, the beds of arid zone rivers are dry for most of the time, and infrequent runoff peaks quickly come and go. The intermittent nature of such rivers (often indicated as Wadis) can be associated with long-term precipitation deficits inherent to arid climate. This causes evaporation and evapotranspiration to play a much more dominant role in the hydrological cycle than in humid climates, thereby reducing the role of streams. Rainfall-runoff relation at arid and semiarid catchments is very complex in comparison to wet catchments or catchments with relatively high streamflow/rainfall ratio.

The monthly water balance models are developed and widely employed to estimate rainfall-runoff relation at many catchments throughout the world. Xu and Singh [3] reported that the monthly water balance model is mainly applied in three fields; i.e. reconstruction of the hydrology of the catchments, assessment of climatic change impacts, and evaluation of the seasonal and geographical patterns of water supply and irrigation. Several monthly water balance models have been developed in the past and now are used by many hydrologist. Some of these models are simple, whereas others are complex. Most of these models are used to aid researchers and engineers working in the field of water resources planning and development.

Monthly water balance models were first developed in the 1940s by Thronthwaite [4]. Thronthwaite water balance model is considered as the first attempt to establish a realistic approach for converting precipitation into runoff (in monthly basis). The model uses an accounting procedure to analyze the allocation of water among various components of the hydrologic system. Thornthwaite and Mather [5] developed a set of deterministic monthly water balance models. The models contain only two parameters: one is soil moisture capacity Ø, and the other is the surplus water above maximum soil moisture storage capacity Ø. Pitman [6] developed a monthly water balance model, which is widely used throughout South Africa. Alley [7] examined Thornthwaite and Mather models. He concluded that in spite of their simplicity, these models have been shown to reasonably estimate monthly runoff .

In the 90s of the last century, numerous water balance models were developed and were employed in the studies related to water resources and climatic change. Some of these studies [8-10] used a spatially aggregated monthly water balance model to model the upper lakes and five sub-basins of the Nile River basin. Yates and Strzepek [11] developed a three-parameter monthly water balance model and applied it on Nile River basin to assess potential climatic change impacting Nile runoff. Xiong and Gue [12] developed a monthly water balance model which includes only two parameters. They have reported that their model proved to be quite efficient in simulating monthly runoff. Abulohom *et al.* [13] developed a five-parameter monthly water balance model. They have stated that the model performance was quite well. Loukas and Vasiliades [14] reported that Abulohom's monthly water balance model was found to be the most efficient in simulating the runoff hydrograph and runoff volume from Yermasoyia watershed at Cyprus.

More than half a century of development, monthly water balance models have experienced many changes, which make these models more complicated in terms of data requirements and number of parameters. Beven [15] states that three to five parameters should be sufficient to reproduce most of the information in a hydrological record. Gleick [16] found that the simulation of large watersheds under various climatic change scenarios using daily models were not an improvement over runoff estimates derived from monthly or seasonal hydrologic models.

Therefore, there is a need to stress the development of a simple water balance models, which can reproduce the catchments response utilizing only available limited information. Ye *et al.* [17] found that a six-parameter conceptual model did not yield inferior accuracy to a complex model using 22 parameters in modeling monthly runoff in low-yielding ephemeral catchments.

Because of the sparseness and limitation of available data, particularly at arid and semiarid regions and in agreement with Ye *et al.* [17] findings, a simple six-parameter monthly water balance is proposed in this study and is applied to two arid and semiarid low yielding catchments located at two different regions in the middle east.

2. Model Structure

The model proposed in this study is a conceptual spatially lumped water balance model. The model is mainly based in water balance of the land phase. The basic concept of this model is that it sub-divides the soil moisture storage of the drainage basin within 100 to 300 mm of the soil surface into two stores; the upper layer soil moisture store USM, and the lower layer soil moisture store LSM.

The model uses monthly rainfall, pan evaporation and streamflow record as input data. The outputs from this model are a monthly series of simulated streamflow, upper soil moisture content and lower soil moisture content. A schematic diagram showing the structure of the proposed model is given in Fig. 1.

2.1. Actual monthly evapotranspiration

Evapotranspiration is the process by which water in the land surface, soil and vegetation is converted into vapor state and returns to the atmosphere. It consists of evaporation from water, soil and other surfaces including transpiration by vegetation. Evapotranspiration varies spatially as a result of variation in climate, crop and soils.

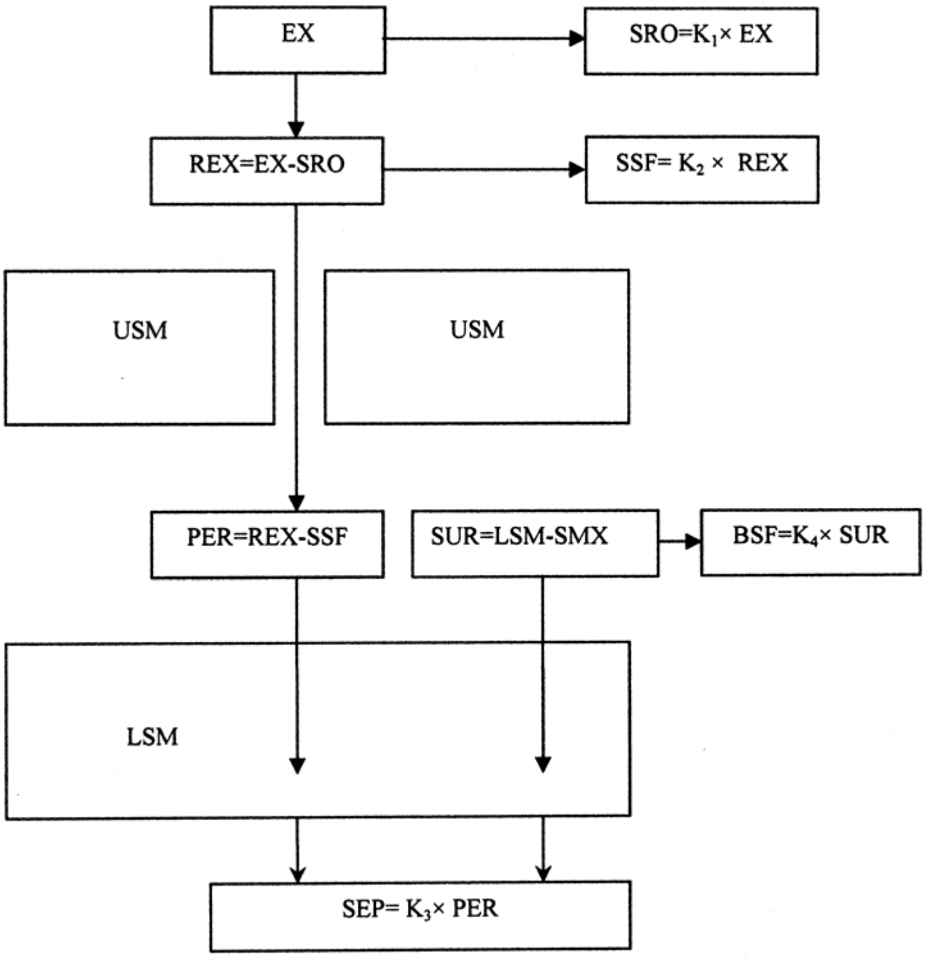

Fig. 1. Schematic representation of the proposed six-parameter monthly water balance model.
USM = upper layer soil moisture content
LSM = lower layer soil moisture content
EX = excess water above the upper layer soil moisture storage capacity
SRO = surface runoff
REX = remaining excess
SSF = subsurface flow
PER = percolation to LSM
SUR = surplus water in excess of the lower layer soil moisture storage capacity
BSF = base flow
SEP = deep seepage

In evapotranspiration studies, the concept of potential evapotranspiration is commonly encountered. Thornthwaite defined potential evapotranspiration as: "the water loss, which will occur if at no time there is a deficiency of water in the soil for the use of the vegetation". In practical sense, however, most investigators have assumed that potential evapotranspiration is equal to lake evaporation as determined from a pan evaporation record.

Many watershed modelers have assumed that the actual evapotranspiration is equal to the pan evaporation multiplied by some coefficient. Other modelers [18] have used "complementary relationship" to calculate actual evapotranspiration. Morton [19] stated that there are still some unsettled arguments about which one of the above mentioned methods could better reflect the feedback mechanism involved in the water cycles.

Xiong and Guo [12] have used different equations to obtain the actual evapotranspiration from the pan evaporation. After many numerical experiments, they have suggested an equation to compute actual evapotranspiration. The suggested equation is:

$$\mathrm{AET(i)} = \mathrm{c} \times \mathrm{PE(i)} \times \tanh\left[\mathrm{P(i)/PE(i)}\right] \tag{1}$$

where AET(i) represents the actual monthly evapotranspiration, PE(i) is the monthly pan evaporation value, P(i) is the monthly rainfall, and c is a co-efficient introduced to take an account of the effect of the change of time scale from year to month on the original equation. They found that the optimum values of this co-efficient scattered around unity.

In this study, many formulas have been tested to compute actual evapotranspiration from pan evaporation. Equation (1) is found to be more appropriate to compute actual evapotranspiration provided that the amount of monthly rainfall P(i) is greater than zero. The value of co-efficient c in this equation was adjusted between 0.5 and 1. When the monthly rainfall is zero, the author assumed that the actual evapotranspiration from the upper soil store may occur at a rate proportional to the soil moisture status which is given by:

$$\mathrm{AET(i)} = \mathrm{USM(i-1)} - \mathrm{USM(i-1)} \times \exp\left[-\left(\mathrm{PE(i)}/\mathrm{USMX}\right)\right] \tag{2}$$

where UMS(i-1) is the upper layer soil moisture content at the beginning of the month (i), PE(i) is the monthly pan evaporation, and USMX is the maximum moisture storage capacity of the upper soil layer.

If this layer is empty, actual evapotranspiration occurs continuously from the lower layer soil store at a rate proportional to the soil moisture status at this layer which is given by:

$$\mathrm{AET(i)} = \mathrm{LSM(i-1)} - \mathrm{LSM(i-1)} \times \exp\left[-(\mathrm{PE(i)} / \mathrm{LSMX})\right] \tag{3}$$

where LSM (i-1) is the lower layer soil moisture content at the beginning of month (i), LSMX is the maximum moisture storage capacity of the lower soil layer. USMX and LSMX marks the upper and lower limits for USM and LSM. In this study, USMX and LSMX are the first and second model parameters. Their values should be obtained by optimization technique, and the optimum values should be within the range from 20 to 150 mm.

2.2. Numerical methods for the proposed model

In this study, the upper layer soil moisture storage is augmented by monthly precipitation (P) and depleted by the actual monthly evapotranspiration (AET) which occurs continuously, as given by Eq. (1). When monthly rainfall is zero, then actual evapotranspiration occur from upper soil layer store as given by Eq. (2).

The upper layer soil moisture storage uses a continuous function based on water balance which is given by:

$$\mathrm{USM(i)} = \mathrm{USM(i-1)} - \mathrm{P(i)} - \mathrm{AET(i)} \tag{4}$$

where P(i) is the monthly rainfall. If the upper layer soil moisture store is empty, the actual evapotranspiration is occurring consequently from the lower layer soil moisture store according to Eq. (3). This process is continued until the upper layer soil moisture storage exceeds its maximum threshold value (USMX). At this stage, the consequent processes could be illustrated as follow:

1) The excess water, $EX_{(i)}=USM_{(i)}-USMX$, is partly diverted into the surface and flow as surface runoff, $SRO_{(i)}=K_1(EX_{(i)})$ (K_1 is the third model parameter).
2) The remaining excess water, $REX_{(i)}=EX_{(i)}-SRO_{(i)}$, will flow in part as subsurface flow, $SSF_{(i)}=K_2(REX_{(i)})$, and in part will percolate downward to augment the lower layer soil moisture storage, $PER_{(i)}=REX_{(i)}-SSF_{(i)}$ (K_2 is the fourth model parameter).
3) Lower layer soil moisture store LSM, is continuously augmented by percolation from the upper layer soil store, $PER_{(i)}$ and depleted by base flow, $BSF_{(i)}$, deep seepage $SEP_{(i)}$, and actual evapotranspiration (which occur only when the upper layer store is empty).
4) Deep seepage $SEP_{(i)}$, is occurring continuously at each month as, $SEP_{(i)}=K_3(LSM_{(i)})$, (K_3 is the fifth model parameter).
5) Base flow component is assumed to take place when the lower layer soil moisture storage exceeds its upper limit (LSMX). The surplus water, $SUR_{(i)}=LSM_{(i)}-LSMX$, the base flow is then given by: $BSF_{(i)}=K_4(SUR_{(i)})$ (K_4 is the sixth model parameter).

The lower layer soil moisture store uses a continuous water balance function to describe water movement into and out of its conceptualized storage. This function is given by:

$$LSM_i = LSM_{i-1} + PER_i - BSF_{i-1} - SEP_{i-1} \tag{5}$$

(when USM $_i$> 0 and PER $_i$> 0)

$$LSM_i = LSM_{i-1} - BSF_{i-1} - SEP_{i-1} \tag{6}$$

(when USM$_i$>0 and PER $\le$ 0)

6) When the upper layer soil moisture store USM$_i$ is less or equal to zero, and the surplus water SUR$_i$ is greater than zero, the surplus water is added to augment the upper layer soil moisture store, USM$_i$ = USM$_i$+SUR$_i$, and the base flow BSF$_i$ for the current month (i) will be equal to zero.
7) The total simulated monthly runoff Qsim$_i$ is the sum of surface runoff SRO$_i$, subsurface flow SSF$_i$ and baseflow BSF$_{i-1}$ (taken with one month lag).

$$Qsim_i = SRO_i + SSF_i + BSF_{i-1} \tag{7}$$

where Qsim$_i$ is the simulated monthly runoff (m^3/s).

2.3. Determination of initial soil moisture content

The value of initial soil moisture content could have an appreciable effect on the quality of simulation processes, especially when the data series used is not sufficiently long. It helps in predicting the level of saturation in the catchments prior to the application of the model. Precise determination of the soil moisture content will definitely increase the accuracy of simulation results, and consequently will help to enhance the model performance.

In this study, moisture content at the upper and lower soil layers are initially assumed zero, then the model is run using all data series available for calibration and validation. The first year of the calibration and validation is considered as the model initialization year which is necessary for the model to reach equilibrium. Initial soil moisture content of the upper and lower soil stores are assumed equal to the moisture content at the beginning of the second year of both calibration and validation.

3. Model Calibration

The parameters of watershed model, in general, can not be determined directly from physical characteristics of the catchments, and hence the parameters values must be estimated using observed data. Calibration is the determination of a parameter set that gives a simulated hydrological series which adequately matches the observed series. There are two broad approaches to watershed model calibration: manual and automatic.

In the automatic approach, model calibration problem is formulated as optimization problem, so computer-based optimization methods can be employed to compute the optimal model parameters. The success of automatic calibration depends on model structure, calibration data, calibration criteria and optimization method.

In this study, Shuffled Complex Evolution (SCE.UA) optimization method developed by Duan *et al.* (1992) is employed to optimize the parameters of the proposed model. SCE.UA is a powerful global optimization technique, originally designed to deal with the peculiarities encountered in the conceptual watershed model calibration.

4. Model Validation

The validity of any model depends on its accurate representation of the hydrological process. It would be an easy task if the calibrated parameters obtained through the application of optimization technique can be generalized as optimal parameters. Actually, in watershed hydrological modeling, another procedure is required to verify the acceptability of this calibration. These procedures are called model evaluation or validation. Therefore, if the parameters resulted from the calibration of a certain set of hydrological data are inserted in the model as input to another set of hydrological data, the resulted output (i.e., streamflow) should be reasonably close to the observed streamflow. The model is considered as valid only when the performance is satisfactory in both calibration and validation.

5. Assessment of the Model Performance

The classical approach to fit a rainfall-runoff model to observe data is to obtain an optimum parameter set which minimizes or maximizes an objective function of observed and simulated flow. Many objective functions have been developed and applied to rainfall-runoff modeling. In this study, different objective functions are used to assess the performance of the proposed model. All these objective functions are used separately and interchangeably to evaluate the parameters of the proposed model.

The first function used in the present study is the well known least square objective function which is probably one of the most widely used in model calibration. Least square objective function is given by:

$$\mathrm{OF(LS)} = \frac{\sum_{i=1}^{N} (\mathrm{Qobs}_i - \mathrm{Qsim}_i)^2}{N} \tag{7}$$

where Qobs_i is the observed flow at any month i, Qsim_i is the simulated flow on any month i, N is the total number of months. The least square objective function evaluates the sum of flow residual. The value of OF should be close to zero for a good simulation of the monthly runoff. The second objective function used is the relative error in volume between the observed and simulated flow, which is defined by:

$$RE = \frac{\sum_{i=1}^{N} (Qobs_i - Qsim_i)}{\sum_{i=1}^{N} Qobs_i} \times 100 \qquad (8)$$

,

For a good match between the total observed and simulated volume, RE should be close to zero. Both objective functions presented above are not normalized and the function values, which are dependent on flow values, can differ by several order of magnitudes. This means that it is not possible to compare relative model performance between different catchments, which is necessary in this study. Therefore, an auxiliary approach to optimization is the use of Nash efficiency criterion [20], which is defined by:

$$R^2 = 100 \left[1 - \frac{\sum_{i=1}^{N} (Qobs_i - Qsim_i)^2}{\sum_{i=1}^{N} (Qobs_i - \overline{Qobs})^2} \right] \qquad (9)$$

where $\overline{Qobs_i}$ is the observed streamflow over the calibration period N. A perfect agreement between the observed and simulated flow yields a value of R^2 closer to 100%, while a negative R^2 represents a lack of agreement worse than if the simulated flows are replaced with the observed monthly flow.

6. Model Application and Catchments Description

Two different catchments are selected to test the proposed model; one is arid and the other is a semiarid. Wadi Wala catchment is an arid ephemeral catchment located in the central part of Jordan. The topography of the catchment varies drastically; the highest altitude is about 900 m above sea level at the extreme north, whereas the lowest altitude is about 350 m above sea level at the south west of the catchment.

The rainy season in Jordan in general begins in October and lasts until May. The rest of the year is practically dry. Because of the low ratio of the mean annual precipitation to the mean annual evapotranspiration, Wadi Wala is classified as arid catchment. Orographic precipitation and convective thunder storms have been recorded in the Wala catchment, especially at the beginning and/or at the end of winter season, causing sharp peaks of flash floods because of the high intensity of rainfall. The average annual rainfall over Wadi Wala catchment is approximately 300 mm and the average temperature is 15°C.

The other catchment used in testing the proposed model is Wadi Zabid catchment, which is located in the south west of Yemen. The catchment area of Wadi Zabid has an area of about 4750 km^2. The topographic elevation in Wadi Zabid catchment varies drastically; the highest parts of the catchment are at the elevation over 3000 m. Most of catchment area is higher than 1500 m. The general climatic pattern of the catchment is sub-tropical semiarid.

The regional rainfall characteristics depend on the orientation of the topography to the main rain bearing winds. The mean annual rainfall varies from 800 mm in the upper catchment area to 100 mm in the coastal plain. The main physical and climatic characteristics of Wadi Wala and Wadi Zabid catchments are all given in Table 1.

Table 1. Summary of physical and climatic characteristics of the two catchments used for this study

Catchment	Wadi Wala	Wadi Zabid
Period of record	1969–1998	1970-1998
Area (km^2)	1800	4750
Altitude (m)	350–900	100–3000
Rainfall (mm / year)	289	750
Runoff (mm / year)	13.1	71
Pan evaporation (mm / year)	1740	2200
Runoff coefficient	0.05	0.095

7. Results and Discussion

The proposed six-parameter monthly water balance model have been calibrated and validated using the available data collected from Wadi Wala and Wadi Zabid catchments. The optimize parameters of the proposed model for both Zabid and Wala catchments are shown in Table 2.

Table 2. Optimized parameter values for the catchments under study

Parameter	USMX	LSMX	K_1	K_2	K_3	K_4
Wadi Wala	53	67	0.169	0.045	0.182	0.000
Wadi Zabid	29	147	0.078	0.097	0.435	0.016

Table 3. Simulation results at the two catchment under study

Catchment	Calibration period			Validation period		
	Number of months	R^2	RE(%)	Number of months	R^2	RE(%)
Wadi Wala	168	90	+ 4.13	144	87	- 3.1
Wadi Zabid	168	80	+ 5.26	168	80	- 11

Simulation results, such as the values of Nash-Sutcliff criterion R^2, and the relative error between the observed and simulated flow volume RE, are all given in Table 3. The coefficient of efficiency in both catchments is always greater than 80%. The values of R^2 on Wadi Wala catchment are 90% for calibration and 88% for validation. The values of R^2 in Wadi Zabid are 88% for calibration and 80% for validation. The values indicate that the simulation results in both catchments are good. The model performs well on both catchments, during both calibration and validation period. The performance on Wadi Wala during the validation period is better than on Wadi Zabid. This is clearly indicated by a low value of R^2 on Wadi Zabid, R^2 = 80% as compare to Wadi Wala, R^2 =88%. Chiew and McMahon [21] state that simulation with R^2 = 80% are always considered to be acceptable for typical hydrological studies.

The total simulated flow volumes are nearly within 4% of the total recorded flow volume on Wadi Wala catchment, and within 11% of the total recorded flow volume on Wadi Zabid. The values of RE on Wadi Wala catchment are + 4.13 for calibration and -3.1 for validation. The values on Wadi Zabid are +5.26 for calibration and -11 for validation. It appears that the values of RE in both catchments are always greater on calibration than on validation. Simulation results of Wadi Wala catchment are demonstrated in Fig. 2, which shows the observed and simulated monthly runoff hydrographs during the validation period.

Similarly, Fig. 3 shows the observed and simulated monthly runoff hydrographs during the validation period at Wadi Zabid catchment. The simulated upper and lower series of soil moisture content are respectively shown in Figs. 4 and 5 for Wadi Wala catchment, and in Figs. 6 and 7 for Wadi Zabid catchment. All the simulated maximum monthly runoff is plotted respectively in Figs. 8 and 9 against the corresponding maximum monthly observed runoff for both Wala and Zabid catchments.

The values of correlation co-efficient between the series of simulated and observed peaks for both Wala and Zabid catchments are also provided in these figures. Figures 8 and 9 clearly demonstrate that all the simulated and observed peak values are very close to the regression line. This indicates that the model is also capable to produce the maximum monthly runoff hydrographs reasonably well at both catchments used in this study.

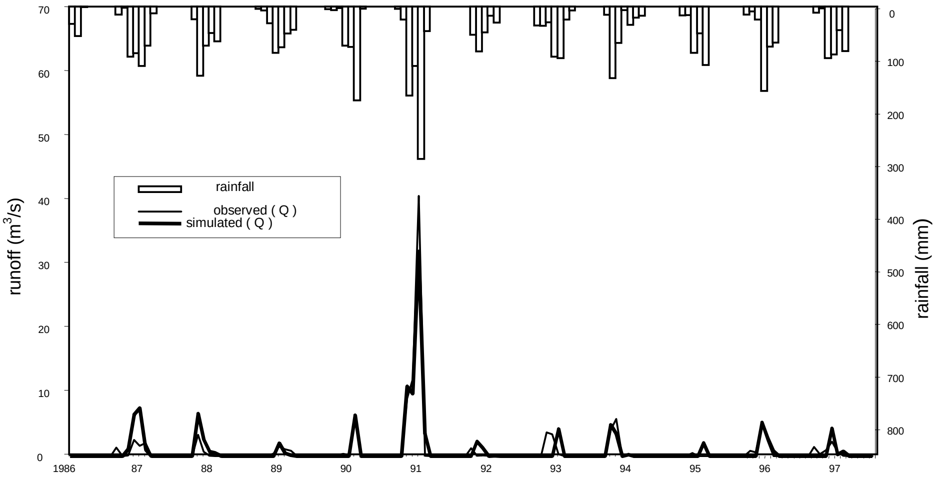

Fig. 2. The observed and simulated monthly runoff hydrographs at Wadi Wala catchment in the central part of Jordan.

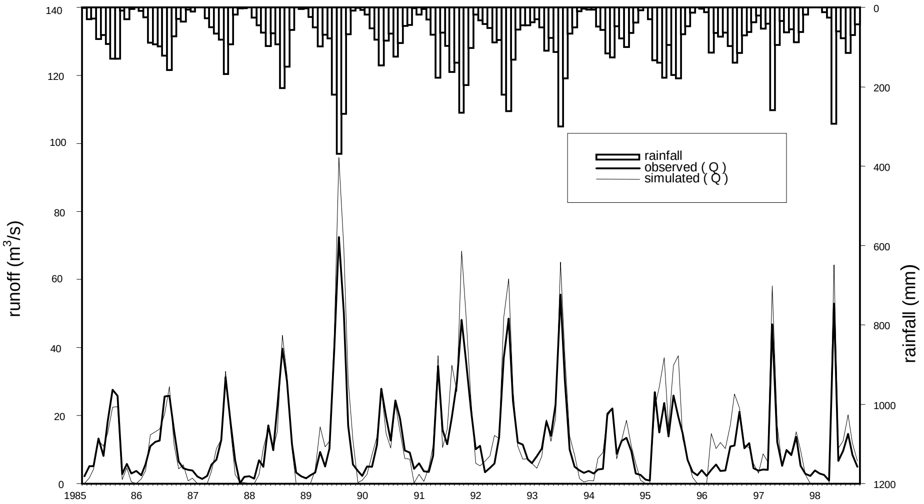

Fig. 3. The observed and simulated monthly runoff hydrographs at Wadi Zabid catchment in the south west of Yemen.

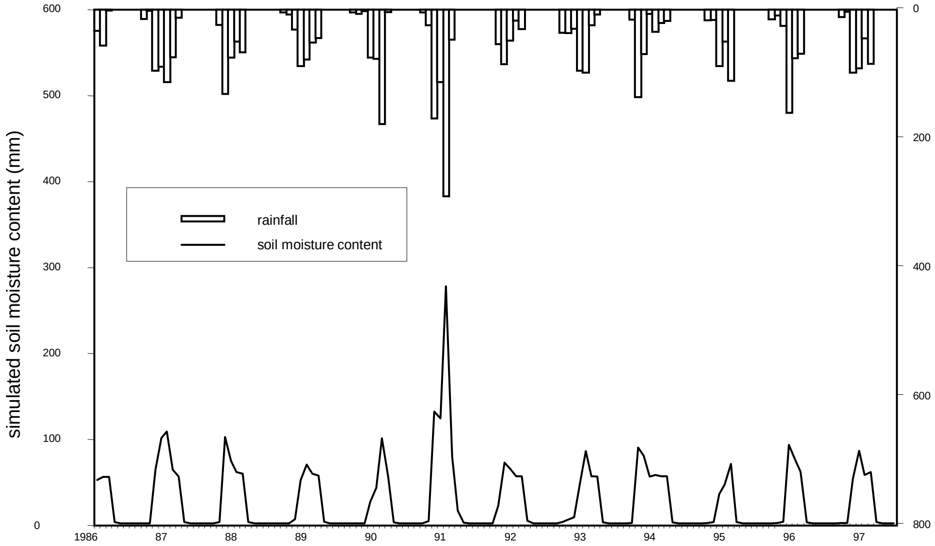

Fig. 4. The simulated upper layer soil moisture content series at Wadi Walla catchment.

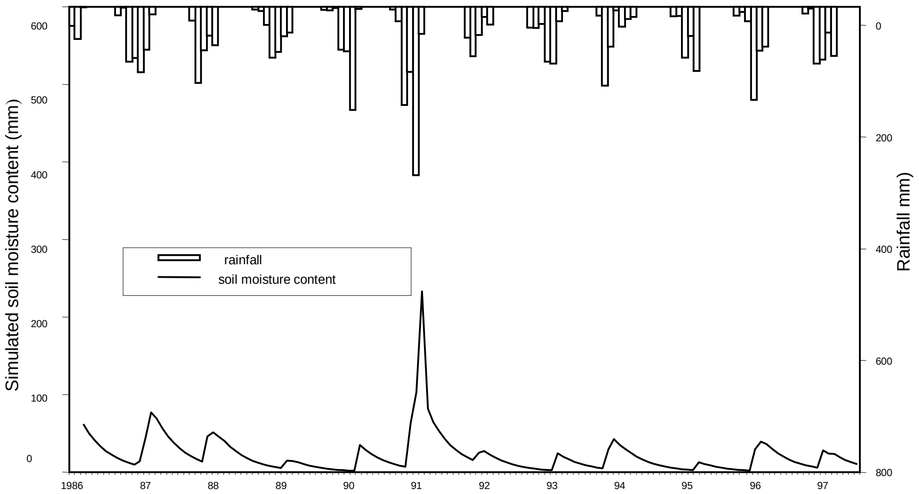

Fig. 5. The simulated lower layer soil moisture content series at Wadi Wala catchment.

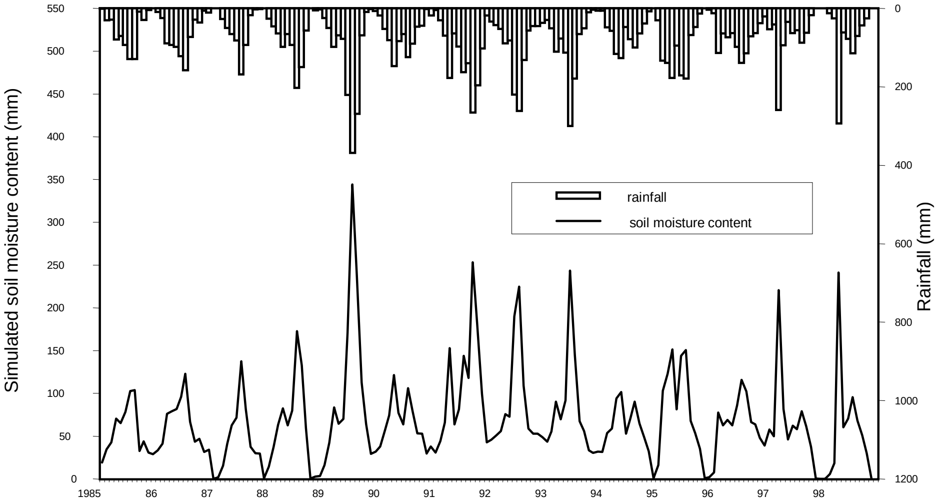

Fig. 6. The simulated upper layer soil moisture content series at Wadi Zabid catchment.

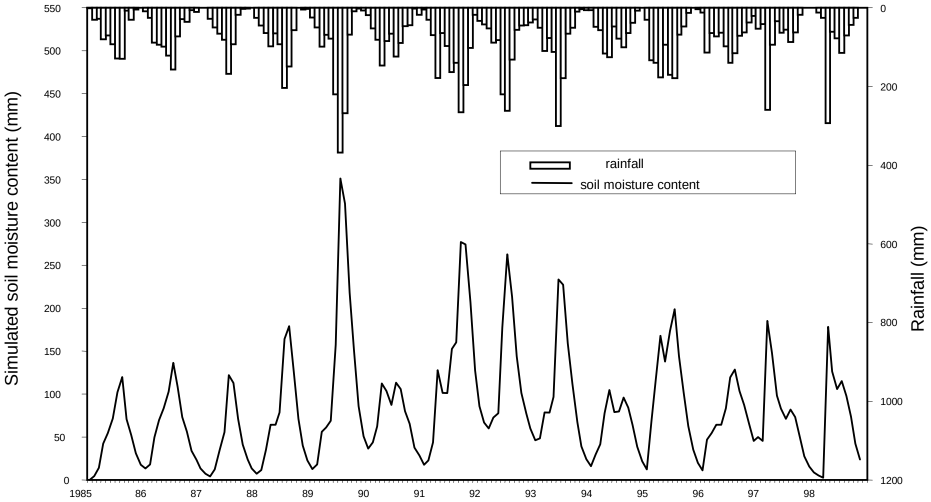

Fig. 7. The simulated lower layer soil moisture content series at Wadi Zabid catchment.

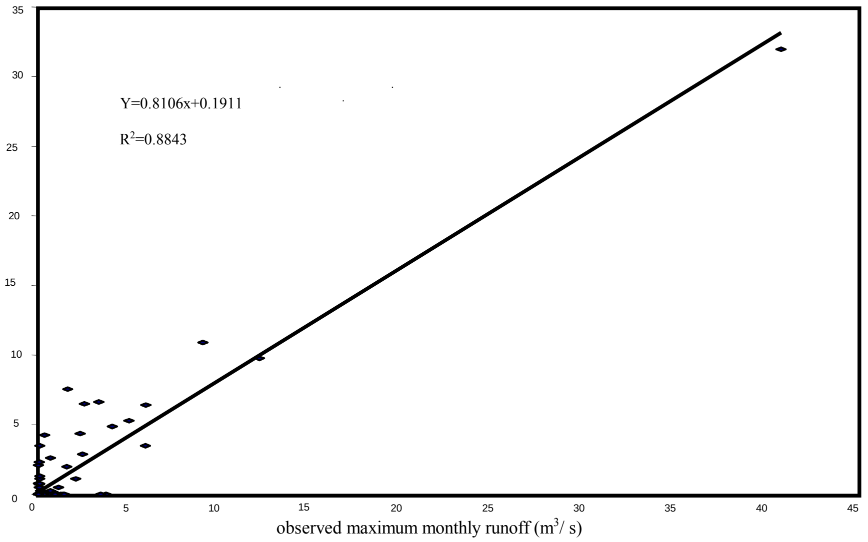

Fig. 8. The observed and simulated maximum monthly runoffs on Wadi Wala catchment.

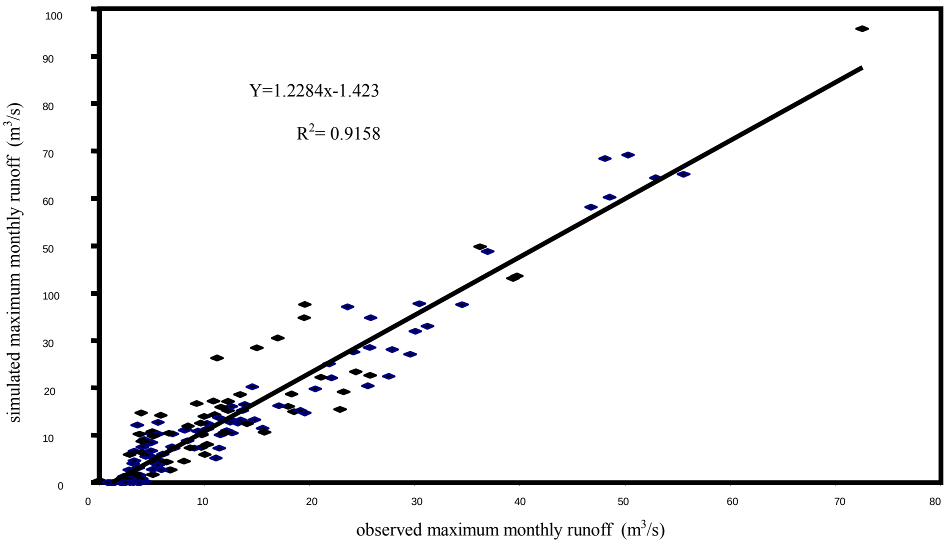

Fig. 9. The observed and simulated maximum monthly runoffs on Wadi Zabid catchment.

8. Conclusions

Based on the results obtained on this study, the following conclusions are drawn:

1. The proposed six-parameter water balance model is capable of simulating the monthly runoff hydrographs in both arid and semiarid catchments. Its performance is slightly better on Wadi Wala catchment than on Wadi Zabid catchment
2. The optimum values of the ground water flow co-efficient K_4 fall very close to zero on Wadi Zabid catchment, and exactly zero on Wadi Wala catchment. The low values of the coefficient K_4 indicates that the contribution of the base flow component to the total flow is very minor at arid and semiarid catchments, and this suggest that the optimization of the parameter K_4 is not necessary, particularly at arid catchments where it may be set to zero. This is supported by the fact that at arid catchments, Saturation contact between streams and regional groundwater reservoir is relatively rare. The simulation of base flow at semiarid catchments may improve the overall simulation of runoff at these catchments.
3. Simulation of deep seepage is extremely important at arid and semiarid catchments. Deep seepage can represent a significant portion of effective rainfall. It constitutes nearly 20% of the total effective rain lost to the catchment.
4. The simulated runoffs are always larger than the observed runoffs. This is indicated by a lower value of RE (less than zero) observed at both catchments. The numerous man-made terraces on the mountain of Wadi Zabid catchment and the widespread runoff harvesting practices at Wadi Wala catchment offer convincing arguments for the variation between observed and simulated runoff at these catchments.
5. Good simulation results obtained by the proposed modeling approach suggest that the proposed model is theoretically sound and accurate, practically simple, fast and efficient for monthly runoff prediction at arid and semiarid catchments. The model will be useful in effective management of water resources at arid and semiarid low yield catchments.
6. The modeling approach suggested in this study is based on simple assumptions in order to seek some synthesis of the watershed characteristics and climate on the monthly runoff yield of an arid and semiarid catchments. Therefore, there is a need for improving the modeling concept to address the lack of understanding of some complex processes and data deficiency problems.

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نموذج بستة وسائط للموازنة المائية الشهرية وتطبيقاته في الجوابي الجافة وشبه الجافة ذات الجريانات المنخفضة

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(قدِّم للنشر في ٢٦/٠٣/٢٠٠٥م ؛ وقبل للنشر في ٢٦/٠٩/٢٠٠٦م)

ملخص البحث. تم تطوير نموذج للموازنة المائية الشهرية. من المزمع أن يتم استخدام هذا النموذج لأغراض محاكاة الجريانات الشهرية في الجوابي الجافة وشبه الجافة, والتي في الغالب تعاني من الافتقار الحاد للمعلومات الهيدرولوجية، وفي حال توفر هذه المعلومات فإنها تكون متغايرة وبشكل كبير في الزمان والمكان. تم معايرة واختبار النموذج المقترح باستخدام بيانات تم جمعها من جابيتين مختلفتين في الشرق الأوسط ؛ الأولى تقع في اليمن والأخرى في الأردن. أظهرت النتائج المستحصلة بأن النموذج حقق تطابقا جيدا بين الجريانات الشهرية الملاحظة والمحاكاة.

تدل نتائج تطبيق النموذج على أن النموذج المقترح يعد قويا من الناحية النظرية وبسيطا من الناحية العملية ويعتبر كفؤا لغرض تخمين الجريانات الشهرية في الجوابي ذات الجريانات المنخفضة. وسيكون النموذج مفيدا لأغراض الإدارة والتخطيط الأمثل للموارد المائية في المناطق الجافة وشبه الجافة.