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Impermanent Changes Investigation of Shape Factors of the Volumetric Balance Model for Water Development in Surface Irrigation

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ABSTRACT: One of the most methods for design of surface irrigation is volume balance model. This model, assumed that the shape factors are constant. This assumption cause significant errors in computations. In this paper was investigated the variations of the shape factors relation to time by Valiantzas' method. This method based on combination of volume balance and kinematic wave models. Results of the method as advance curve had a good agreement with field data. So the method proved that subsurface shape factor was variable relation to time and all its values was more than its constant value in initial volume balance method. The variation of surface shape factor was less than the other factor.
Keywords: volumetric balance model; Surface irrigation; water advancement ; variation ; Valiantzas' method

INTRODUCTION

One of the important parameters in planning the surface irrigation is computation of the time (period) of water advancement. Volumetric balance (VB) models are one of the simplest methods employed for this purpose.

This model has two shape factors one of them concerns the surface flow and the other one is relevant to the subsurface (Intrusive) flow. In the primary VB model, these factors are considered relative to the constant time, while this does not correspond with reality. Elazba and Al-Azba (1) in 1994 stated that constant assuming of VB model factors leads to considerable error in the water advancement computations in surface irrigation.

In the primary VB model, shape factor of surface flow is assumed to be 0.77 and for the shape factor of subsurface flow, equations are presented all of which are independent of time amongst which equations of Heart et al. (2) in 1968 and walker and Walker (3) in 1987 can be mentioned. The first one has presented the subsurface flow shape factor as a function of power of the percolation equation and the second, as a function of power of the percolation equation and power of the advancement equation. To modify these factors, Hall (4) in 1956 presented a numerical method for computing the subsurface flow in which distribution and rate of the subsurface flow is a function of time.

Valiantaze (5) in 1993 by combining the VB model with the zero inertia models computed the volume of surface flow and studied its variations without using the surface flow shape factor. Also this researcher in 1997 (6, 7) presented a series of equations for the above said factors as a function of time.

MATERIALS AND METHODS

Primary model of volumetric balance is presented as follows (6):

$$Q_0.t = \sigma_y.A_0 x + \sigma_z.Z_0.x \qquad (1)$$

Where Q_0 = inflow rate t=time from the beginning of inflow rate A_0= flow cross section at the entry point, Z_0= percolated surface at the entry point (product of percolated water depth by width of the strip or furrow), x= advancement interval, σ_y = surface flow shape factor, σ_z = subsurface flow shape factor.

Shape factors are defined as below (6):

$$\sigma_y = \frac{\int_0^x A(s,t)ds}{x.A_0} \tag{2}$$

$$\sigma_z = \frac{\int_0^x Z.ds}{x.Z_0} \tag{3}$$

If at time t, advancement is equal to x, A (s, t) is the surface flow cross section at distance s from entry point which varies between A_0 to zero and also Z is the percolated surface at the distance s from the entry point which varies between Z_0 to zero (8-12).

σ_y and σ_z values in equations (2) and (3) change relative to time. Waliantaze has reported equations for these coefficients as below which have been used in this paper (5 and 6):

Study of σ_y changes:

Waliantaze employed the kinematic model to investigate σ_y changes in sloped strips and furrows equations of which are as Follows:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} + aKt^{a-1} = 0 \tag{4}$$

$$\frac{Q^2 n^2}{\rho_1 A^{\rho_2}} = s_0 \tag{5}$$

Where,

N= the manning roughness coefficient, S_0=slope of the strip floor or furrow and *a* and *K* are the coefficients of Kostianov percolation equation ρ_1 and ρ_2 are strip or furrow shape factors:

$$Z = Kt^a \tag{6}$$

$$A^2 R^{1.33} = \rho_1 A^{\rho_2} \tag{7}$$

That in the above equation R is the hydraulic radius.

By changing of the below variable, variables of equations 4 and 5 decrease:

$$x* = \frac{x}{x_r}\ ,\ t* = \frac{t}{t_r}\ ,\ Q* = \frac{Q}{Q_r}\ ,\ A* = \frac{A}{A_r} \tag{8}$$

Where:

$$Q_r = Q_0\ ,\ A_r = A_n\ ,\ t_r = \left(\frac{A_r}{K}\right)^{\frac{1}{a}}\ ,\ x_r = Q_r.t_r / A_r \tag{9}$$

Where:

An= flow cross section proportionate to the normal depth (obtained employing the Manning equation as for the flow rate Q_0).

Following changing the equation 8 variables in equations 4 and 5 and their combination, a new equation is obtained which was solved by Waliantaze via the numerical method of finite differences from solution of which a various times, cross section changes alongside the advancement route is obtained through which using equation 2, σ_y can be computed at various times. Waliantaze drew the σ_y changes relative to time, for different *a* and ρ_z for which using statistical regression presented the following equation:

$$\sigma_{y_{\min}} = 0.8 + 0.055\rho_2^{1.3} - 0.47a^{0.6} \tag{10}$$

Where $\sigma_{y\ \min}$ is the minimum σ_y this researcher following specifying the minimum and maximum σ_y, proposed its changes relative to time through the following equation:

$$\left(\frac{\sigma_y.x*}{t*}\right)^{1+a} = \frac{\sigma_y - \sigma_{y_{\min}}}{1-\sigma_{y_{\min}}} \tag{11}$$

By solving the above relation through the trial and error procedure, σ_y value at any time can be computed.

2. Study of σ_z changes:

To study the σ_z changes waliantaze employed the Hall technique which has been modified by Elezba and sterikov (1).

Using the above method, σ_z changes relative to time for various values of *a* was studied. σ_z Values stand between the two R_0 and R_1 parameters. These two parameters are as follows:

$$R_0 = \frac{1}{1+a} \tag{12}$$

$$R_1 = \frac{a.\pi.(1-a)}{\sin(a\pi)} \tag{13}$$

Now, if parameter s is defined as follows:

$$s = \frac{\sigma_z - R_1}{R_0 - R_1} \tag{14}$$

Regarding σ_z variations, s variations will be between zero and one. Waliantaze concluded that s variations are independent of a (while σ_z variations are dependent on a). H attributed the s variations to the parameter W as follows:

$$s = 2.6W^2 - 1.6W^3 \tag{15}$$

Which

$$W = \left(\frac{x*}{t*}\right)^{\frac{1}{a+1}} \tag{16}$$

Therefore in a specified time, using equations 12 to 16, σ_z can be computed.

Using the equations presented in the previous section, VB can be employed with variable coefficients (relative to time) and perform the water advancement computations relative to time.

To determine X in lieu specified time t, operations are performed as follows:

In exchange of a knows flow rate Q_0 and shape factors ρ_1 and ρ_2 and strip or furrow floor slope and the Manning roughness coefficient, A_0 value is computed from the equation (5) (A_0= A_n).

R_0 and R_1 values are computed using the equations 12 and 13 and the percolation function.

$\sigma_{y\min}$ is computed using equation 10.

σ_z and σ_y are assumed (for the first assumption σ_y = 0.77 and σ_z = (R_0+R_1) (2)

Percolation value at the beginning following time t is computed using the Kostiakov percolation equation (Z_0).

X value is computed using equation (1).

X^* and t^* values are computed employing the equations 8 and 9.

The W value is computed using the equation 16.

S value is computed using the equation 16.

σ_z value is computed using the equation 14 and σ_y values are computed using equation 11. (To compute σ_y, on the left side of the equation 11 instead of σ_y, the value assumed in section 4 is placed).

With new values of σ_z and σ_y, the value of X is computed from the equation 11.

In case the X values computed from the stages 11 and 6 differ, computations are repeated with σ_z and σ_y of stage 11 until the X values computed from the stages 11 and 6 become sufficiently close to each other. Thus, the last X is the advancement distance at the time t and the last σ_z and σ_y too, is considered as the shape factors in time t.

All the above computations in this research have been performed using a computer program.

It should be mentioned that instead of Kostiakov percolation equation it is possible to employ any other percolation equation.

For this purpose, the following modifications should be done:

1. Z_0 should be calculated using the new percolation equation
2. Instead of power a in the above method the following equation must be used.

$$a = \frac{Log Z_t / Z_{0.5t}}{Log 2} \qquad (17)$$

Where:
Z_s should be computed from the new percolation equation.

RESULTS

In this research, measurement of percolation speed, advancement and shape factors were performed on seventeen farms in Isfahan the summary of which data for two types of farms is presented in the following table.

Using the presented method and the above data, σ_y and σ_z variations relative to time are computed and presented in figures 1 and 2. Also, advancement computations in various farms were done that compared with data on field measurements; precision of the method presented in this paper is confirmed. As shown in figures 3 and 4, the difference between results of this method and the field data is negligible.

DISCUSSION

The method presented in this paper enjoys high precision. However, this method depend on the normal cross section to compute which the strip or furrow floor slope must be known and therefore for flat strips or furrows (with zero slope) this method cannot be applied (13-15). On one hand, precision of the kinematic wave model in flat and low sloped lands decreased and in this method, this model has been used to study the σ_y variations (16-20).

In such a condition the zero inertia models must be used.

Regarding figures 1 and 2 it can be seen mean σ_y for farms 1 and 2 was 0.73 and 0.74 respectively that in the primary VB model its value is assumed to be 0.77. σ_z measured by the relations presented for them is independent of time (like Heart of walker relations) for both farms is about 0.5 while regarding figures 1 and 2, their variations are between 0.56 to 0.74. Therefore Relations presented for σ_z (independent from time) do not enjoy sufficient precision. For other strips results similar to the above results were obtained (21-25).

Table 1. Data from two research fields

Characteristics	$q_0 (m^3/\min/m)$	s_0	a	K(m/min^a)	n	Soil texture
Farm 1	0.135	0.001	0.7947	0.0040158	0.08	Silty loam clay
Farm 2	0.20232	0.005	0.7936	0.0045813	0.18	Clay loam

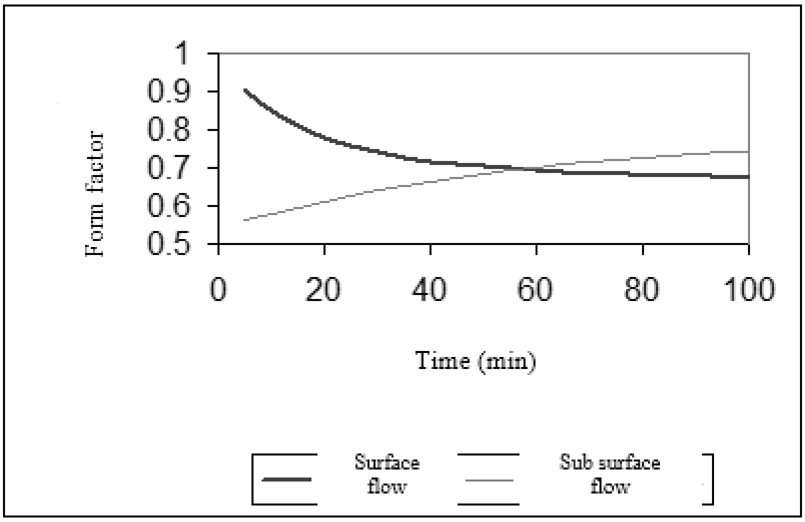

Figure 1. Coefficient of variation on the farm (1)

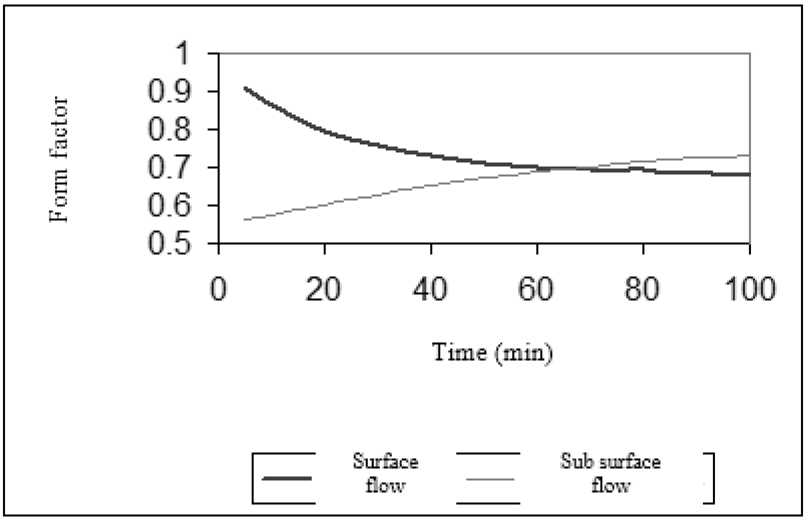

Figure 2. Coefficient of variation on the farm (2)

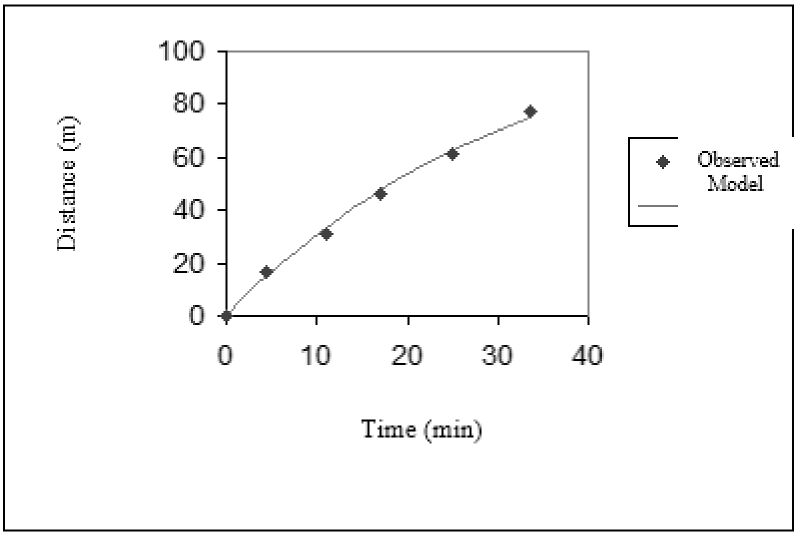

Figure 3. Comparison model results with field data for the farm (2)

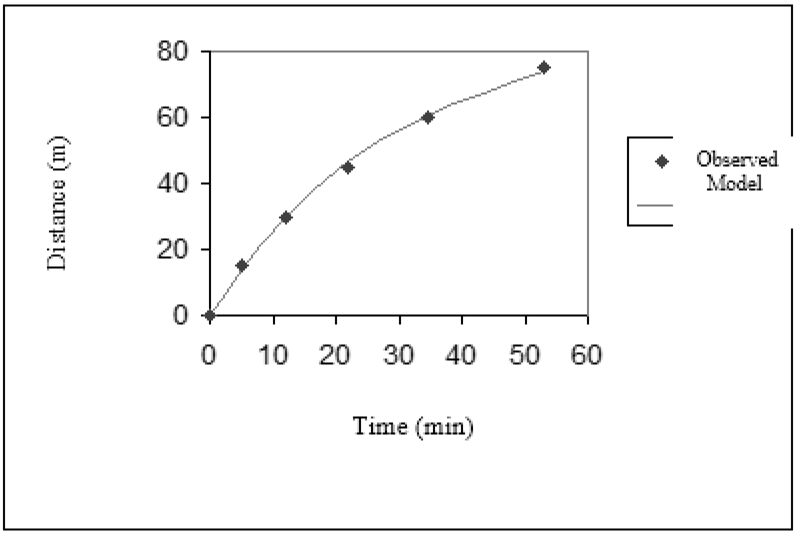

Figure 4. Comparison model results with field data for the farm (1)

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