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Efficiency, Adequacy, and Uniformity for Normal Distribution of the Application Depths

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Abstract

The research aims to find a set of figures in case of the normal distribution of application depths that represent relationships for the parameters used to describe the performance characteristics of the irrigation system. Using 6010 values for each of the dimensionless application depth, dimensionless cumulative area, and the coefficient of variation, with the help of the SPSS statistical program, an empirical equation was obtained to estimate the dimensionless application depth as a function of the dimensionless cumulative area and the coefficient of variation. Five figures were developed containing the relationships between dimensionless net depth of irrigation, application uniformity, coefficient of variation or uniformity coefficient, application efficiency or deep percolation losses, and storage efficiency or deficit coefficient. By knowing two of these parameters, the rest of them can be easily found from these figures.

Keywords: *normal distribution, uniformity, efficiency, storage efficiency*

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1. INTRODUCTION

The distribution of the application depths corresponding to the area are linear distribution and normal distribution [1]. In sprinkler irrigation, the distribution of the application depths usually coincides with the normal distribution and corresponds to its average value when the Christensen uniformity coefficient for irrigation depths is greater than 70% [2, 3]. At lower uniformity coefficients, it is closer to a linear than to a normal distribution [4]. In drip irrigation, system can be considered to have a normal distribution due to its high uniformity distribution [5]. Where for surface irrigation, it is closer to the linear distribution than to the normal distribution [1]. [6] Used a statistical method to divide infiltration depths into net irrigation and deep percolation based on a normal distribution and mentioned that this method has the ability to find the average irrigation depth required to get full yields for a specific part of the field.

A set of equations were derived to express both storage efficiency and deficit coefficient as a function of both application adequacy and application uniformity and a function of the application adequacy and deep percolation losses [7]. The efficiency, adequacy and uniformity of irrigation are parameters for designing and evaluating the performance of the irrigation system. When high efficiency irrigation is combined with a good water distribution uniformity, this reflects positively on water use efficiency and productivity [8]. There is no adequate and efficient irrigation without good uniformity [9]. The efficiency of any irrigation system related to the uniformity of water distribution and affected by any change that occurs to it [10]. In addition, managing the irrigation system requires finding efficient irrigation and distribution [11].

In the normal distribution of infiltration depths, there are no relationships between the efficiency, uniformity and adequacy of irrigation and deep percolation, and these parameters are important in the design and evaluation of irrigation projects. Therefore, the research aims to find a set of figures in case of the normal distribution of application depths. The figures represent relationships expressing parameters that used to describe the performance characteristics of the irrigation system: the application adequacy, the coefficient of variation or uniformity coefficient, the application efficiency or the deep percolation losses, and the storage efficiency or the deficit coefficient.

2. DISTRIBUTION OF DIMENSIONLESS APPLICATION DEPTHS

By adopting the standard normal distribution and 601 values of the standard variable Z from -3 to 0 to +3 with an interval of 0.01, the dimensionless cumulative area Q (Z) with values from 0 to 0.5 to 1 was found from the following cumulative distribution function [12]:

$Q(Z)=0.5ERF[Z/2^{0.5}]$ ……..…………….….. (1)

If y represents the application depth, $\bar{y}$ the average of application depths and s.d. the standard deviation of application depths and equation 2 is the formula for the Z↔ y transformation:

$y= Z*s.d. + \bar{y}$ ……………..... (2)

Dividing equation (2) by $\bar{y}$ yields:

$Y=Z*CV+1$ …………………..... (3)

Where Y is the dimensionless application depth and CV is the coefficient of variation, which is equal to the quotient of the standard deviation divided by the mean ((s.d.) / $\bar{Y}$). And 601 has a standard Z value from -3 to 0 to +3 with an interval of 0.01, The dimensionless application depth Y was found from equation (3) at different values of CV from 0.05 to 0.5 with an interval of 0.05, thus, we have 6010 values for each of the variables: Y, Q, CV. Using the SPSS statistical program, an empirical equation (4) has been derived to estimate the dimensionless application depth Y as a function of the dimensionless cumulative area Q and the coefficient of variation CV, with determination coefficient R^2=0.999 and RMSE=0.0475:

$Y=f(Q)=(2.99Q^{0.05}+0.37Q^{0.15}-3.33Q^{0.25})\ CV^{0.98}/(0.47-0.46Q^{0.25})-5.99Q^{0.2}CV^{0.98}+1$ ……...(4)

Figure (1) shows the equilibrium between the dimensionless application depths calculated from equation (3) and estimated from equation (4). Figure (2) shows the distribution of the estimated dimensionless application depths from equation (4) with the dimensionless cumulative area for different variation coefficients.

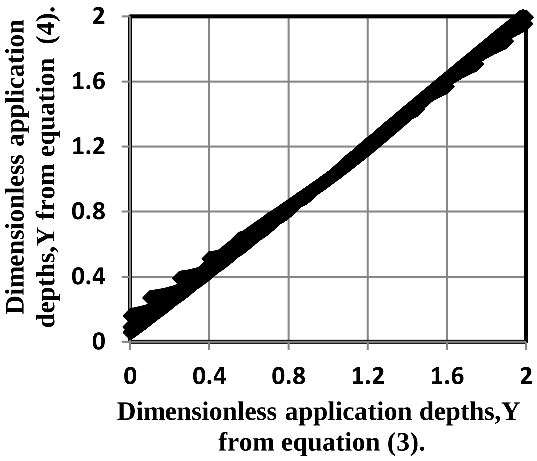

Figure (1):The comparison between the dimensionless application depths calculated from equation (3) and estimated from equation (4).

3. IRRIGATION SYSTEM PERFORMANCE CHARACTERISTICS

There are many parameters that are used to characterize the performance characteristics of the irrigation system [1, 7, and 13] in addition to what is

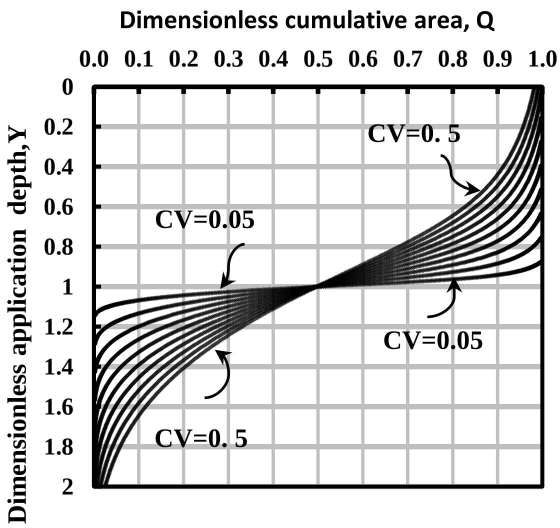

Figure (2): Distribution of the dimensionless application depths with the dimensionless cumulative area for different coefficients of variation.

related to monitoring the infiltration depths within the root zone of a particular crop during the growing season resulting from the addition of irrigation water and loss by water consumption and deep percolation. Figure (3) shows the normal distribution of the dimensionless application

depths with the dimensionless cumulative area, area a1 represents the irrigated water stored in the root zone. Area a2 represents irrigation water that penetrates below the root zone, and area a3 represents the deficit of irrigation water in the root zone. The parameters characterize the performance characteristics of the irrigation system are:
First: Application adequacy. It is the ratio of the area receiving application depth equal to or greater than the net depth of irrigation NDI to the total area; it represents A in Figure (3).

The depth of irrigation expresses the dimensionless net depth of irrigation (NDI) (Irrigation water required in the root zone) when Q is equal to A in equation (4):

$$NDI= (2.99A^{0.05}+ 0.37A^{0.15} -3.33A^{0.25}) CV^{0.98}/(0.47-0.46A^{0.25})-5.99A^{0.2}CV^{0.98}+1 \quad \ldots\ldots\ldots\ldots (5)$$

Second: Application Efficiency gives a general indication of how well an irrigation system is performing [14], it represents the ratio of irrigation water stored within the root zone to the amount of water given. Accordingly, application efficiency E is the following:

$$E=a1/ (a1+a2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

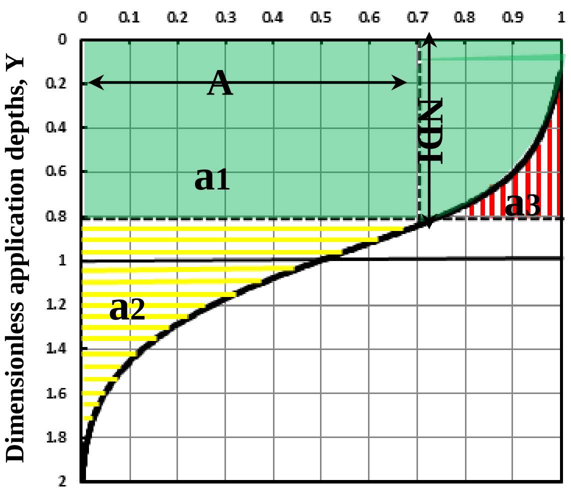

Figure (3: The normal distribution of the dimensionless application depths with the dmensionless cumulative area.

$$E= [NDI*A+\int_A^1[\ f(Q)]*dQ]/ (1*1) \quad \ldots (7)$$

Third: Deep percolation is the ratio of the irrigation water penetrated below the root zone to the amount of water given, and it expressed in P:

$$P=a2/ (a1+a2) =1-E \quad \ldots\ldots (8)$$

Fourth: Application Uniformity, which expresses the regularity of irrigation water distribution. The UCH uniformity coefficient and its relationship with the CV coefficient are [15, 16]:

$$CV=1.25\ (1-UCH) \quad \ldots\ldots (9)$$

Fifth: Storage Efficiency, which is the ratio of the amount of water stored to the required amount in the root zone, and it expressed in ES:

$$ES= a1/(a1+a3) \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

$$ES= [NDI*A+\int_A^1 f(Q)*dQ]/ (NDI*1) \quad \ldots (11)$$

$$ES =A+\int_A^1 f(Q)*dQ / NDI \quad \ldots\ldots (12)$$

$$ES=E / NDI \quad \ldots\ldots (13)$$

Sixth: The deficit coefficient is the ratio of the amount of deficit in irrigation water to the irrigation water required in the root zone, and it expressed in DC:

$$DC=a3/ (a1+a3) = 1- ES \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

4. RESULTS AND DISCUSSION

Based on equation (5), the dimensionless net depth of irrigation was calculated for several values of coefficient of variation from 0 to 0.625 or equivalent to that for the uniformity coefficient according to equation (9) for different levels of application adequacy from 0.5 to 1. Figure (4) shows the relationship between the dimensionless net depth of irrigation and the coefficient of variation or uniformity coefficient, for different application adequacies.

The application efficiency was also found from equation (7) or its equivalent from deep percolation according to equation (8) for several values of the coefficient of variation from 0 to 0.625 or equivalent to that for the uniformity coefficient for different levels of application adequacy from 0 to 1. Figure (5): shows the relationship between application efficiency and deep percolation losses with the coefficient of variation or uniformity coefficient, at different levels of application adequacy.

The storage efficiency was found from equation (12) or its equivalent from the deficit coefficient according to equation (14) and for several values of the coefficient of variation from 0 to 0.625, or equivalent to that for the uniformity coefficient, for different levels of application adequacy from 0 to 1. Figure (6) shows the relationship between storage efficiency or deficit coefficient with the coefficient of variation or uniformity coefficient for different application adequacies.

The storage efficiency was found from equation (13) and for several values of application efficiency from 0 to 1, or equivalent to that for deep percolation losses according to equation (8), for different levels of the dimensionless net depth of irrigation from 0 to 1. Figure (7) shows the relationship between storage efficiency or deficit coefficient with application efficiency or deep percolation losses for different values of dimensionless net depth of irrigation. The data obtained from equation (7) for application efficiency and the data obtained from equation (12) for storage efficiency were used to clarify the relationship between the storage efficiency or the deficit coefficient with the application efficiency or deep percolation losses at different levels of application adequacy in Figure (8).

5. CONCULOSION

There are five groups of parameters used to characterize the performance characteristics of the irrigation system: the dimensionless net depth of irrigation, the application adequacy, the coefficient of variation or the uniformity coefficient, the application efficiency or the deep percolation losses and the storage efficiency or deficit coefficient. From knowing two of them, the rest of the parameters can be determined easily from Figures (4-8). An example of this presented in Table (1) and indicated on the Figures, from knowing the dimensionless net depth irrigation and the coefficient of variation or coefficient of uniformity.

Table (1): Coefficients for characterizing the performance characteristics of the irrigation system.

dimensionless net depth of irrigation	**0.75**
application adequacy	**0.8**
coefficient of variation or uniformity coefficient	**0.35 or 0.72**
application efficiency of or deep percolation losses	**0.72 or 0.28**
storage efficiency or deficiency coefficient	**0.96 or 0.04**

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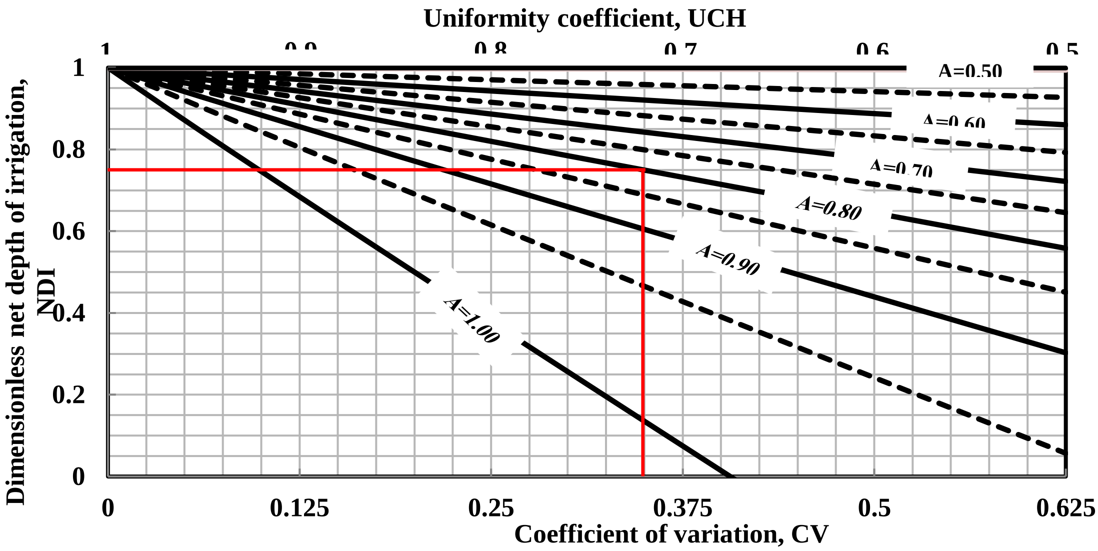

Figure (4): Relationship between the dimensionless net depth of irrigation, uniformity coefficient and coefficient of variation, at different application adequacies.

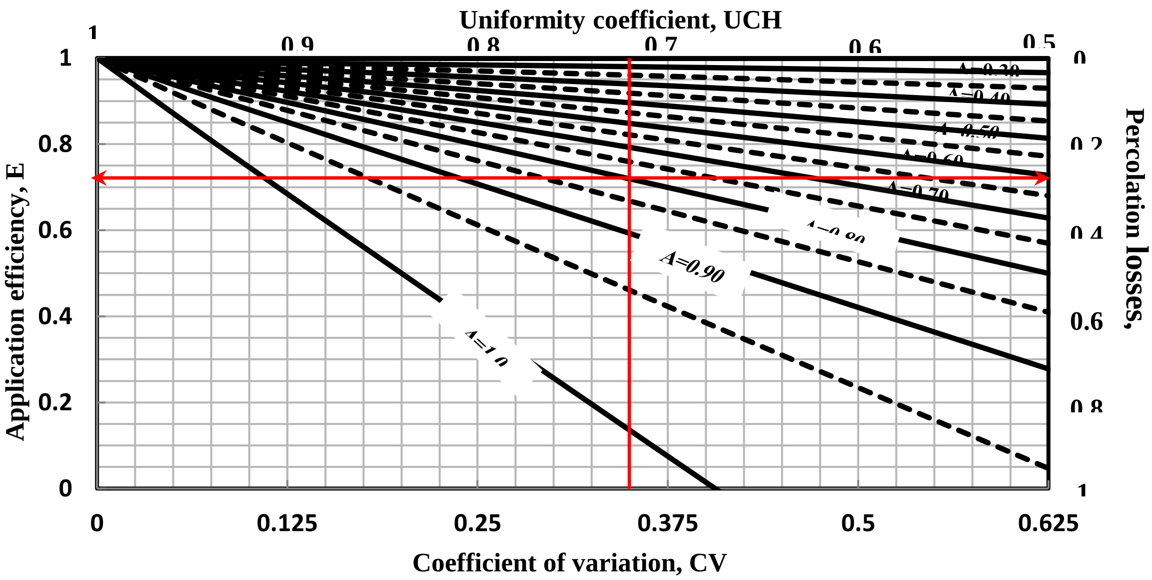

Figure (5): Rrelationship between application efficiency, uniformity coefficient, deep percolation losses and coefficient of variation, at different application adequacies.

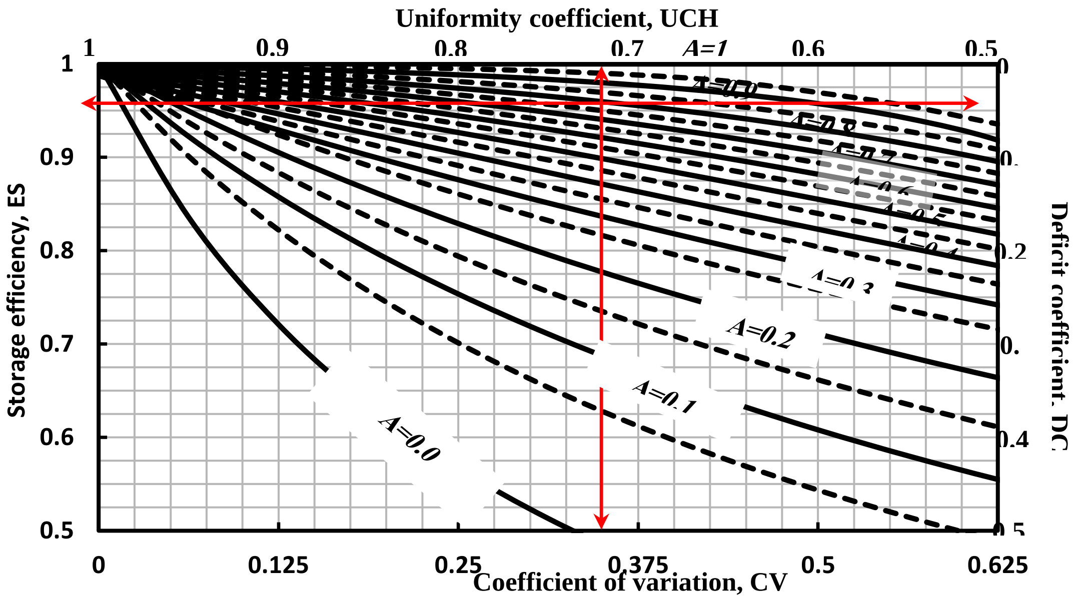

Figure (6): The relationship between storage efficiency, uniformity coefficient, deficit coefficient, and coefficient of variation at different application adequacies.

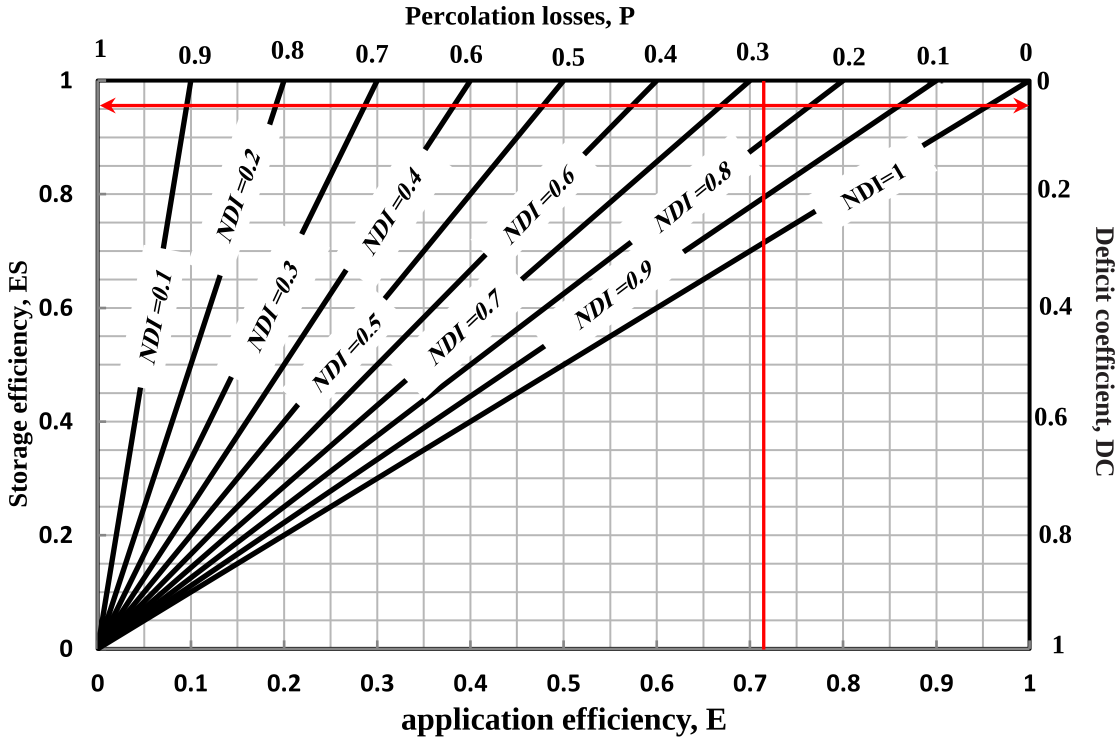

Figure (7): Relationship between storage efficiency, deep percolation losses, deficit coefficient, and application efficiency at different values of dimensionless net depth of irrigation.

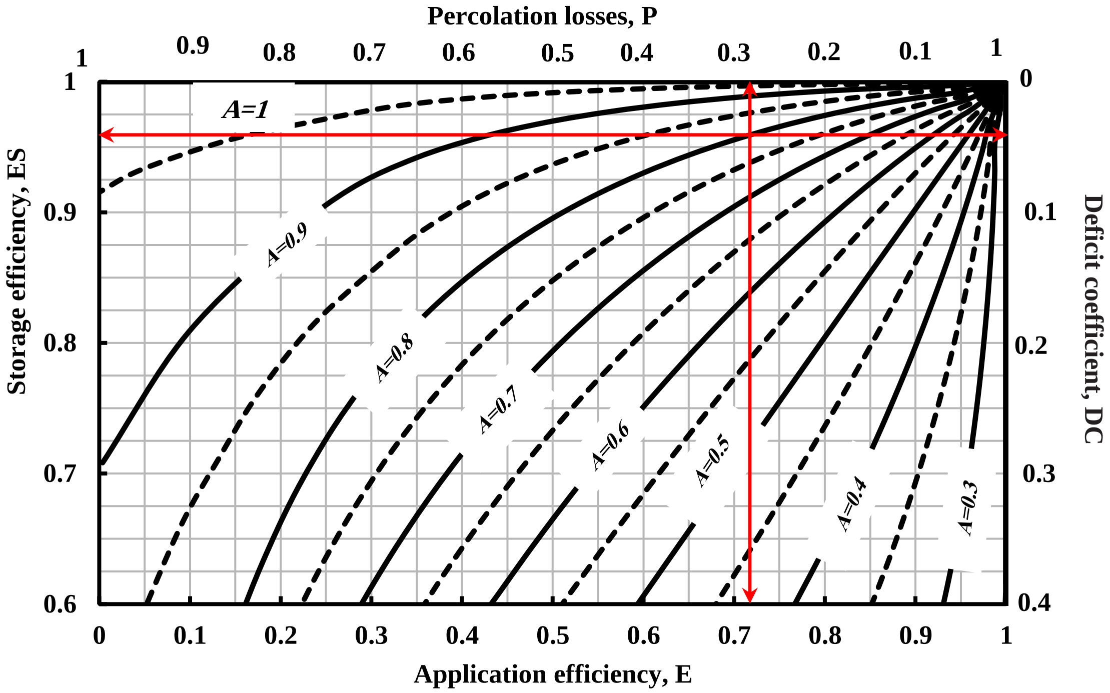

Figure (8): Relationship between storage efficiency, deep percolation losses, deficit coefficient, and application efficiency at different application adequacies.

الكفاءة والكفاية والتناسق للتوزيع الطبيعي لأعماق الارواء

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الخلاصة:

يهدف البحث إلى إيجاد مجموعة مرتسمات في حالة التوزيع الطبيعي لأعماق الارواء تمثل علاقات تعبر عن المعاملات التي تستخدم لتوصيف خصائص أداء منظومة الري. فباستخدام 6010 قيمة لكل من عمق الارواء اللابعدي والمساحة التراكمية اللابعدية ومعامل التغاير وبمساعدة البرنامج الاحصائي SPSS تم ايجاد معادلة تجريبية لتخمين عمق الارواء اللابعدي كدالة للمساحة التراكمية اللابعدية ومعامل التغاير. تم اعداد خمسة مرتسمات تتضمن العلاقات بين صافي عمق الارواء اللابعدي، وكفاية الارواء، ومعامل التغاير أو معامل التناسق، وكفاءة الارواء أو ضائعات التخلل العميق، وكفاءة الخزن أو معامل العجز، حيث يمكن بسهولة من معرفة اثنين من هذه المعاملات ايجاد البقية من هذه المرتسمات.

الكلمات الافتتاحية: *التوزيع الطبيعي، كفاءة الارواء، كفاية الارواء، معامل التناسق، كفاءة الخزن.*