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Validation and Verification of Hedia Computer Model for Sprinklers Overlapping Design

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As one of the main water saving irrigation technologies, sprinklers irrigation systems are used globally owed to the advantages like wide adaptability and easily automated operation. Sprinkler application uniformity is an important indicator in the evaluation of design irrigation quality. HEDIA mode has been instated to select the more acceptable design of sprinklers geometric overlapping pattern depending upon Christiansen uniformity coefficient. The model used one sprinkler superimposition technique and double cubic spline interpolation method in generating the overlapping pattern water data. HEDIA computer model has been validated by CATCH3D model Version 4.6. Their results indicated that CATCH3D model can't accurately calculate the even triangular sprinklers overlapping pattern shape data and failed in predicting sprinkler water distribution pattern from several radii data additionally the difficulty use of that model. Conversely, HEDIA has been succeeded in simulating all sprinklers overlapping patterns shapes from grid or radial data. The created model can use just one quarter part sector or one radial data in generating the sprinkler distribution pattern data in lab test then directly applicant the overlapping patterns calculations with simplicity deal. So, HEDIA computer model can serve as a decision support model in designing sprinklers overlapping patters.

Keywords: sprinkler spatial distribution, superimposition technique, sprinklers overlapping patterns, Christiansen uniformity coefficient, HEDIA, CATCH3D.

Introduction

Improper design in sprinklers irrigation system lead to poor water distribution, non-uniform crop growth and excessive water application in some areas with insufficient in others so, it decrease yield per unit of area and per unit of water application (Issaka et al., 2019). Developing a comprehensive understanding of sprinklers design interrelationships would require an enormously expensive and time consuming field tests (Karimi, et al., 2022 and Acar, et al., 2020). The alternative to the hard research through field evaluation is through the theoretical studies which several investigations used it in improving design simulation models (Chen, et al., 2023; Zhang, et al., 2023; Hui, et al., 2021; Gokyay, 2020 and Robles, et al., 2019). Those models used in estimating the water distribution patterns, uniformity analysis and spacing optimization under controlled and uncontrolled conditions. One of the most wide use computer models is CATCH3D model which simulate and graph the sprinklers water distribution uniformity of rectangular or triangular overlapping patterns based on DOS (Allen, 1992). HEDIA computer model was created by Visual Basic, MATLAB and Excel software with its powerful functions to simulate sprinklers overlapping patterns by the superimposition technique. The objectives of this study were to verify HEDIA computations and simulations to the water distribution pattern of sprinklers overlapping at various spacing and geometrical layouts. This model can serve as a support tool for sprinklers irrigation layout design to ascertain optimum spacing for uniform water distribution pattern. Verification of HEDIA computer model was accomplished by CATCH3D model.

Methods and Materials

1. Model Description:

A theoretical formula for the distribution of application depths is needed to covert radials data to grid data depending up on radial point location. Computer simulation model used to estimate a map of application depth grid data built from radial data points with an acceptable accuracy, via cubic spline interpolation method. If available data points are characteristically in radial data points, there are a number of data points along each radial line and the

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data points have the same spacing except the first one which take 1/2 space from sprinkler. When a grid data points required to generate from radial data points a computer simulation used double cubic spline interpolation method to convert radial data points into grid data point by scheming radial data on grid data. So, any point in the grid data points can be estimated by finding the circle container of it, that contain the same location points application. Estimate circle container (radius) for any grid point like Pi with the angle or position of that point on the circle used to calculate water application depth in that point. So, for any grid data points (Pi) to calculate water application depth on it we must find the radius (Ri) and angle θi of that point as in figure (1). Where Pi the grid data point location, X and Y are the two-dimensional grid coordinates of point Pi and Ri and θi are calculate polar radius and angle of point Pi. Ri fixes the magnitude of P_{iLn} (circle intersection points) on all lines L_n (radius data lines) intersect the circle container of grid data point Pi which used to calculate the near actual data point by the position angle of it.

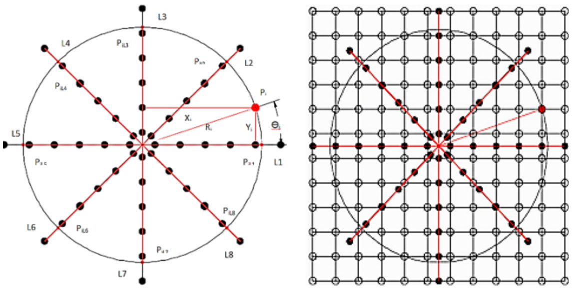


Fig. 1. Convert radial data to grid data points in HEDIA computer model.

Double cubic spline interpolation clarified as in figure (1), there are eight radial lines (L_1, L_2, L_3, L_4, L_5, L_6, L_7 and L_8), with six catch cans placed along each of which. For each radial line the first cubic spline interpolation conducted between the six catch cans (depth of water) placed on that line. The second cubic spline interpolation performed between points located in the same circle intersects radial lines (P_{iL1}, P_{iL2}, P_{iL3}, P_{iL4}, P_{iL5}, P_{iL6}, P_{iL7} and P_{iL8}), and the same work done for all grid data points to get all grid data **(Tomas et al, 2019 ; Li, et al, 2015 and Wenting, et al, 2013**). Cubic spline relies on constructing a polynomial of third degree between each pair of data points because higher the degree of spline the smoother piecewise curve. Illustration of natural cubic spline interpolation method by **(Robert, 2015)** reported that natural cubic spline function S(x) exist N number of piecewise cubic polynomials $S_k(x)$ with coefficients $A_{K,0}$, $B_{K,1}$, $C_{K,2}$ and $D_{K,3}$ for $x \in (x_k, x_{k+1})$ and for k = 0, 1…, N – 1 as satisfies equation (1)

$$S_k(x)=A_K+B_K(X - X_K)+C_K(X- X_K)^2+D_K(X-X_K)^3 \quad (1)$$

Where $S_k(x)$ is piecewise cubic polynomials A_K, B_K, C_K, and D_K are cubic spline coefficients A_K equal y_k which is the magnitude of point space X_K that is known point space and X is the unknown point space. When spline method was chosen to approximate a function represented by the points (X_K,y_k), the first task is to determine the space interval between each two points, h_k, the second task is to calculate the slopes between each points, d_k, and the last task is to obtain the derivatives of the piecewise splines which first and second derivatives of resulting piecewise curve are all continuous on the larger interval. Then calculation of cubic spline coefficients which determined from the following equations:

$$BK= ((Y_{K+1} - Y_K)/h_K)) – [h_k(2m_k + m_{k+1})/6] \quad (2)$$

Where h_k is point space interval, m_k and m_{K+1} are coefficients of second derivative

$$h_k = (x_{k+1} – x_k) \quad (3)$$

$$C_K = m_k / 2 \quad (4)$$

$$D_K= (m_{k+1}–m_k)/6h_k \quad (5)$$

The second derivative piecewise equation of unknown coefficients $m_{k–1}$, m_k, and m_{k+1} for k = 1, 2... N – 1, illustrated as in the following equation:

$$u_k = h_{k–1}m_{k–1} + 2(h_{k–1} + h_k) m_k + h_km_{k+1} \quad (6)$$

Where u_k is the function of two continued slopes and also equal the following:

$$u_k = 6(d_k – d_{k–1}) \quad (7)$$

Where d_k and $d_{k–1}$ are point's location slopes

$$d_k = (Y_{K+1} - Y_K)/(X_{K+1} - X_K)) \quad (8)$$

The second derivative piecewise cubic spline produces several equations correlate second derivative coefficients $m_{k–1}$, m_k, and m_{k+1} with points space intervals and slopes between each point. With the assumption of applicant natural cubic spline, the first and last spline points equal zero then $m_0 = m_N = 0$. So, the second piecewise equation was calculated as follows:

$$u_1=h_0m_0+2(h_0+h_1) m_1+h_1m_2 \quad (9)$$

The immediate piecewise equations were calculated from equation (6) for k = 2, 3... N – 2. The earlier second derivative piecewise cubic spline equation determined from:

$$u_{N–1}=h_{N–2}m_{N–2}+2(h_{N–2}+h_{N–1}) m_{N–1}+h_{N-1}m_N \quad (10)$$

Observing that the unknowns are the desired values $m_{k–1}$, m_k, and m_{k+1} and the other terms are constants obtained by performing simple calculation with the data points (x_k, y_k). Therefore, the second derivative piecewise cubic spline equations are underdetermined system of linear equations involving unknowns so, in matrix form the previous N + 1 equations can be formed as follows:

$$U = H × M \quad (11)$$

Where U is matrix encloses u_k, H is matrix of h_k and M is matrix involving the unknown's coefficients m_k for k = 0, 1, 2... N

Where U, H and M matrixes can be illustrated as follows:

$$U = \begin{pmatrix} 0 \\ 6\left(\frac{y_2 - y_1}{x_2 - x_1} - \frac{y_1 - y_0}{x_1 - x_0}\right) \\ 6\left(\frac{y_3 - y_2}{x_3 - x_2} - \frac{y_2 - y_1}{x_2 - x_1}\right) \\ \vdots \\ 6\left(\frac{y_{N-1} - y_{N-2}}{x_{N-1} - x_{N-2}} - \frac{y_{N-2} - y_{N-3}}{x_{N-2} - x_{N-3}}\right) \\ 0 \end{pmatrix} \quad (12)$$

$$H = \begin{pmatrix} 1 & 0 & 0 & 0 & \cdots & 0 \\ h_0 & 2(h_0 + h_1) & h_1 & 0 & \cdots & 0 \\ 0 & h_1 & 2(h_1 + h_2) & h_2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & h_{N-2} & 2(h_{N-2} + h_{N-1}) & h_{N-1} \\ 0 & 0 & 0 & 0 & \cdots & 1 \end{pmatrix} \quad (13)$$

$$M = \begin{pmatrix} m_0 \\ m_1 \\ m_2 \\ \vdots \\ m_{N-1} \\ m_N \end{pmatrix} \quad (14)$$

Inverse of H matrix must be calculated to get unknown matrix M from equation (11). Finally piecewise cubic polynomials S_K (X) create the cubic spline curve S (X) as follows:

$$S(X) = \begin{cases} S_0(X) = A_0 + B_0(x - x_0) + C_0(x - x_0)^2 + D_0(x - x_0)^3 & \text{if } x_0 \le x \le x_1 \\ S_1(X) = A_1 + B_1(x - x_1) + C_1(x - x_1)^2 + D_1(x - x_1)^3 & \text{if } x_1 \le x \le x_2 \\ \vdots & \\ S(X)_{K.1} = A_{K-1} + B_{K-1}(x - x_{K-1}) + C_{K-1}(x - x_{K-1})^2 + D_{K-1}(x - x_K - 1)^3 \ldots & \\ \ldots\ldots\ldots\ldots\ldots\ldots & \text{if } x_{K-1} \le x \le x_K \end{cases} \quad (15)$$

2. Performance parameters

The performance parameters used to evaluate sprinklers overlapping patterns are water uniformity coefficient, calculated from the water application depths collected in catch cans in the overlapping patterns experiments. Several uniformity formulae have been developed over the past few decades, but the most commonly used is Christensen uniformity coefficient, which defined as follow:

$$UCC=1-\left(\sum_{i=1}^{n}|(X_i-\ddot{X})|\right)/(n\ddot{X})] \quad (16)$$

Where; (X_i) is the individual observation of applied water, $\ddot{X}$ is the mean depth for all observation and (n) is the total number of observation (Christiansen 1942).

Mean Absolute Error (MAE) used as statistical calculation method to comber between output results of two methods of calculations as follows:

$$MAE = (1/n)\left(\sum_{i=1}^{n}|(f_i-y_i)|\right) \quad (17)$$

Where fi, HEDIA simulated values and y_i, CATCH3D simulated values. MAE used to clarify how the simulations close to each other "around 1" (Dwomoh, et al., 2014).

2. Input data for the computational model:

The data required to input in HEDIA computer model are the space between catch cans, water application rates measured around a single sprinkler (mm/h) under selected conditions, overlapping spaces (m) in the desired selected overlapping layout shape (square, rectangle, and triangle). The model procedure support collecting sprinkler precipitations data from radial or grid technique.

Results and Discussion

Verification of the proposed computation model HEDIA by CATCH3D depends on comparing the mean water application depth $\ddot{X}$ and Christiansen uniformity coefficient (UCC) in several overlapping patterns shapes and spaces by MAE. Two sprinkler data categories carried out to simulate the overlapping patterns. The first category depends on grid data input. The second category depends on centrifugal data from one, four and six radials data input.

1- Verification of first category:

In lab test sprinkler top left quarter part sector of water distribution pattern data directly inputted in HEDIA model as to generate sprinkler water distribution pattern automatically then use it in simulating overlapping patterns. However, CATCH3D cannot deal with quarter part sector as HEDIA model, so it was provided with full sprinkler water distribution pattern data although conducting laboratory test. So, sprinkler quarter part sector data of grid lab test has been mirrored manually in all directions to cover the water precipitation pattern area to one individual sprinkler then introduced to the CATCH3D model to simulate the overlapping patterns. So, there was an additional time wasted in performing the mirror process, also in introducing whole sprinkler water distribution pattern rather than a quarter sectors. So CATCH3D model more complex than HEDIA model and loses time and efforts.

Table 1. Comparison between HEDIA and CATCH3D model mean water application depth ($\ddot{X}$, mm/h) and Christiansen uniformity coefficient (UCC, %) of overlapping patterns shape and space in grid data simulation.

Variables	Space	CATCH3D		HEDIA		Space	CATCH3D		HEDIA	
		Square	Triangle	Square	Triangle		Rectangle	Triangle	Rectangle	Triangle
$\bar{X}$	4 × 4	15.55	12.09	15.55	15.55	6 × 8	5.18	3.82	5.18	5.18
UCC		91.3	71.4	91.3	86.17		74.2	63.6	75.5	79.7
$\bar{X}$	6 × 6	6.91	5.29	6.91	6.91	8 × 6	5.18	3.97	5.18	5.18
UCC		82.2	67.4	82.17	82.4		75.5	59.9	74.2	65
$\bar{X}$	8 × 8	3.89	2.87	3.88	3.88	8 × 9	3.46	2.59	3.46	3.46
UCC		74.6	52.8	74.63	64.6		73.4	52.3	72.6	62.8
$\bar{X}$	5 × 5	9.95	9.94	9.95	9.93	7 × 9	3.95	3.33	3.95	3.93
UCC		87.1	84.4	87	86.3		75.9	70.2	75.8	67.7
$\bar{X}$	7 × 7	5.09	5.09	5.07	5.06	9 × 7	3.95	3.28	3.95	3.94
UCC		65.7	68.6	65.7	69.17		75.9	65	75.8	62.4
$\bar{X}$	9 × 9	3.07	3.07	3.07	3.06	9 × 8	3.46	3.45	3.46	3.44
UCC		66.6	73.2	66.6	72.6		72.6	67.9	73.4	65.6

HEDIA and CATCH3D model were run many times with different overlapping shapes and spaces to compare their output results. Table (1) indicates the output results of mean water application depth (Ẍ) and Christiansen uniformity coefficient (UCC) of HEDIA and CATCH3D model. It obvious that the outputs from HEDIA model were similar to that obtained from CATCH3D model in all overlapping shape and space cases expectable in all overlapping shape and space cases expect for even triangle pattern. To verify the error of calculation in CATCH3D even triangle overlapping, for example the mean water application for the selected dimension space of catch cans overlapping patterns must be constant, because sum of sprinkler water perception depth constant and overlapping dimension space constant. As well known, the shape of square or rectangular, triangular overlapping pattern with the same sprinklers overlapping space must take the same mean of water application depth. But in the case of triangular shape with the even data space between sprinklers on lateral, mean water application depth resulted from CATCH3D incorrect; so calculations of uniformity coefficient become incorrect also. Locking to the values of mean water application depth (Ẍ) of even square and triangle overlapping patterns for the CATCH3D model, one could realize the high difference between their values, which are supposed to be equal. This means that the CATCH3D model has problem with the calculations concerning the (Ẍ) values in even triangle pattern. Moreover, this error would affect the calculated values of uniformity which depends on (Ẍ) values. Contrary to that, the HEDIA model gave the same results for (Ẍ) at all patterns having the same overlapping space. For the two models overlapping patterns outputs results MAE used, except for even triangle data so, MAE Ẍ = 0.075 and AME (UCC) = 0.835. These results of AME prove the excitable use of HEDIA computer model and verify its results.

2- Verification of second category:

Verifying the simulation of HEDIA radial technique performed for one radial data simulation "as actual lab test" and for several radials data (four and six) "as filed test". Developed model radial technique compared with CATCH3D model to assure programing codes in generating right part sectors angle and data of sprinkler water distribution pattern.

2.1- Verification of one radial data input:

HEDIA model validated in the case of one radial data simulation by collecting sprinkler water radial data from lab test then input it in the two models then validate the output results. The deviation between the two sprinkler water distribution simulations equal zero. But the hard work done by CATCH3D can be easier by HEDIA model. Because HEDIA model required only the sprinkler radial catch cans water data with its separated space to generate sprinkler water distribution pattern, then directly applicant overlapping by the selected shape and space to indicate the performance parameters of pattern. On the other hand, overlapping simulations in CATCH3D have been accomplished by two steps. The first step depends on feeding the model with radial catch cans water data with its separated space, and then CATCH3D generate the sprinkler water distribution pattern. The second step make user loses a lot of time, because it need user to re-feed the model with the simulated sprinkler water distribution pattern then adjust the best sprinklers overlapping patterns parameters. Table (2) produces the comparison of the mean water application depth and Christiansen uniformity coefficient of several overlapping patterns shapes and spaces for HEDIA and CATCH3D model output results in the case of one radial data input. The same error of calculation by CATCH3D occurred for even triangle with even catch cans space between sprinklers on laterals as in grid simulation. So mean water application depth (Ẍ mm/h) in (4 × 4; 6 × 6; 8 × 8; 6 × 8; 4 × 4; 8 × 6; 8 × 9) catch cans even triangle overlapping patterns shapes generates (12.74; 5.63; 3.04; 4.05; 4.22; 2.73) and (16.4; 7.3; 4.1; 5.47; 5.47; 3.6) for CATCH3D and HEDIA model respectively. On the other hand Christiansen uniformity coefficient (UCC, %) indicated by CATCH3D model are (71.2; 69.6; 57.1; 65; 65.6; 56.6).

Table 2. Comparison between HEDIA and CATCH3D model mean water application depth (Ẍ , mm/h) and Christiansen uniformity coefficient (UCC, %) of overlapping patterns shape and space in one radial data simulation.

Variables	Space	CATCH3D		HEDIA		Space	CATCH3D		HEDIA	
		Square	Triangle	Square	Triangle		Rectangle	Triangle	Rectangle	Triangle
$\bar{X}$	4 × 4	16.4	12.74	16.4	16.4	6 × 8	5.47	4.05	5.47	5.47
UCC		96	71.2	96.27	91.3		80.5	65	80.2	83.4
$\bar{X}$	6 × 6	7.2	5.63	7.3	7.3	8 × 6	5.47	4.22	5.47	5.47
UCC		84.9	69.6	85.99	87.2		80.5	65.6	80.2	72.8
$\bar{X}$	8 × 8	4.1	3.04	4.1	4.1	8 × 9	3.4	2.73	3.6	3.6
UCC		81.4	57.1	81.2	69.7		79.9	56.6	78.5	69.3
$\bar{X}$	5 × 5	10.5	10.49	10.38	10.5	7 × 9	4.17	4.17	4.12	4.16
UCC		90.9	88.8	89.7	86.8		78.2	72.4	78	70
$\bar{X}$	7 × 7	5.36	5.36	5.36	5.35	9 × 7	4.17	4.17	4.12	4.15
UCC		66.7	72.3	66.3	71.58		78.2	69.4	78	69
$\bar{X}$	9 × 9	3.24	3.24	3.24	3.23	9 × 8	3.64	3.65	3.6	3.64
UCC		73.7	76.3	72.1	73.8		79.9	70.2	78.5	67.7

when HEDIA model equal (91.3; 87.2; 69.7; 83.4; 72.8; 69.3).The same error occurred in grid simulation occurred also in radial simulation for even triangle overlapping patterns shape. So, CATCH3D model has a defect in calculating even triangle overlapping pattern shape in grid or radial simulation technique. So, MAE Ẍ = 0.035 and AME (UCC) = 1.06 in the several overlapping patterns beside the even triangle output data for one radial simulation technique. These results also prove the excitable use of HEDIA model and verify its results in radial simulation of one radial data.

2.2- Verification of four radials data inputs:

HEDIA radial technique was established to calculate the magnitude of any point depending on the location of that point from all radials data. So in developed model verification of several radials simulation depend on use numbers of radials data with two radials without water on it (zero) to mark indicator part sector with zero magnitude.

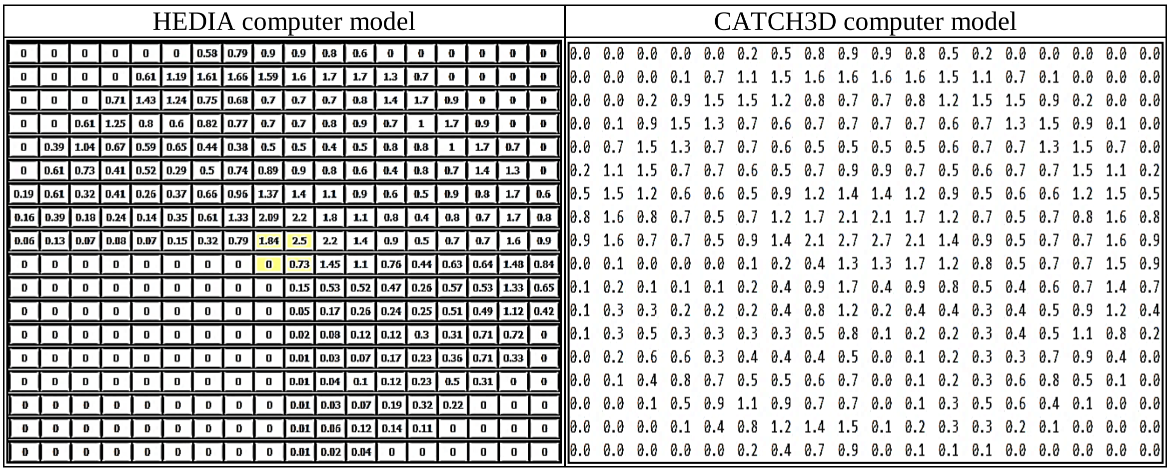
Table 3. four radials data input as in filed test.

	Can1	Can2	Can3	Can4	Can5	Can6	Can7	Can8	Can 9
Radial 1	2.6	2.2	1.4	0.9	0.5	0.7	0.7	1.6	1.9
Radial 2	2.6	2.2	1.4	0.9	0.5	0.7	0.7	1.6	1.9
Radial 3	0	0	0	0	0	0	0	0	0
Radial 4	0	0	0	0	0	0	0	0	0

decreased toward part sector number three conversely data in part sector number four increased toward part sector number one. Plate (1) produces also, CATCH3D simulation of sprinkler water distribution pattern resulted from the same four radials data. The technique of CATCH3D is incorrect, because any data in specific part sector must be generated depending up on the nearest radials data to that part in the two direction of it, but this technique was not used in that model so, the generated data turned out to be inaccurate.

2.3- Verification of six radials data inputs

To instate the opinion, another case study selected with six radials data using zero radials as a guide effect only as previously. Plate (4.23) used to input the six radials data, so the part sector which must has the zero results is the part sector number three with sixty degree part sector angle. Plates (2) show the simulated sprinkler water distribution patterns data from HEDIA and CATCH3D model from the six radials data simulation. HEDIA model outputs results accurately simulated sprinkler water distribution pattern data with its separation angle. So part sector three has been generated with zero magnitude and 60^{o} separation angle. Conversely CATCH3D model not accurately simulated the



HEDIA computer model

0	0	0	0	0	0	0.58	0.79	0.9	0.9	0.8	0.6	0	0	0	0	0	0
0	0	0	0	0.61	1.19	1.61	1.66	1.59	1.6	1.7	1.7	1.3	0.7	0	0	0	0
0	0	0	0.71	1.43	1.24	0.75	0.68	0.7	0.7	0.7	0.8	1.4	1.7	0.9	0	0	0
0	0	0.61	1.25	0.8	0.6	0.82	0.77	0.7	0.7	0.8	0.9	0.7	1	1.7	0.9	0	0
0	0.39	1.04	0.67	0.59	0.65	0.44	0.38	0.5	0.5	0.4	0.5	0.8	0.8	1	1.7	0.7	0
0	0.61	0.73	0.41	0.52	0.29	0.5	0.74	0.89	0.9	0.8	0.6	0.4	0.8	0.7	1.4	1.3	0
0.19	0.61	0.32	0.41	0.26	0.37	0.66	0.96	1.37	1.4	1.1	0.9	0.6	0.5	0.9	0.8	1.7	0.6
0.16	0.39	0.18	0.24	0.14	0.35	0.61	1.33	2.09	2.2	1.8	1.1	0.8	0.4	0.8	0.7	1.7	0.8
0.06	0.13	0.07	0.08	0.07	0.15	0.32	0.79	1.84	2.5	2.2	1.4	0.9	0.5	0.7	0.7	1.6	0.9
0	0	0	0	0	0	0	0	0	0.73	1.45	1.1	0.76	0.44	0.63	0.64	1.48	0.84
0	0	0	0	0	0	0	0	0	0.15	0.53	0.52	0.47	0.26	0.57	0.53	1.33	0.65
0	0	0	0	0	0	0	0	0	0.05	0.17	0.26	0.24	0.25	0.51	0.49	1.12	0.42
0	0	0	0	0	0	0	0	0	0.02	0.08	0.12	0.12	0.3	0.31	0.71	0.72	0
0	0	0	0	0	0	0	0	0	0.01	0.03	0.07	0.17	0.23	0.36	0.71	0.33	0
0	0	0	0	0	0	0	0	0	0.01	0.04	0.1	0.12	0.23	0.5	0.31	0	0
0	0	0	0	0	0	0	0	0	0.01	0.03	0.07	0.19	0.32	0.22	0	0	0
0	0	0	0	0	0	0	0	0	0.01	0.06	0.12	0.14	0.11	0	0	0	0
0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0	0	0	0	0	0

CATCH3D computer model

0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.9	0.9	0.8	0.5	0.2	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.1	0.7	1.1	1.5	1.6	1.6	1.6	1.6	1.5	1.1	0.7	0.1	0.0	0.0	0.0
0.0	0.0	0.2	0.9	1.5	1.5	1.2	0.8	0.7	0.7	0.8	1.2	1.5	1.5	0.9	0.2	0.0	0.0
0.0	0.1	0.9	1.5	1.3	0.7	0.6	0.7	0.7	0.7	0.7	0.6	0.7	1.3	1.5	0.9	0.1	0.0
0.0	0.7	1.5	1.3	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.7	1.3	1.5	0.7	0.0
0.2	1.1	1.5	0.7	0.7	0.6	0.5	0.7	0.9	0.9	0.7	0.5	0.6	0.7	0.7	1.5	1.1	0.2
0.5	1.5	1.2	0.6	0.6	0.5	0.9	1.2	1.4	1.4	1.2	0.9	0.5	0.6	0.6	1.2	1.5	0.5
0.8	1.6	0.8	0.7	0.5	0.7	1.2	1.7	2.1	2.1	1.7	1.2	0.7	0.5	0.7	0.8	1.6	0.8
0.9	1.6	0.7	0.7	0.5	0.9	1.4	2.1	2.7	2.7	2.1	1.4	0.9	0.5	0.7	0.7	1.6	0.9
0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.4	1.3	1.3	1.7	1.2	0.8	0.5	0.7	0.7	1.5	0.9
0.1	0.2	0.1	0.1	0.1	0.2	0.4	0.9	1.7	0.4	0.9	0.8	0.5	0.4	0.6	0.7	1.4	0.7
0.1	0.3	0.3	0.2	0.2	0.2	0.4	0.8	1.2	0.2	0.4	0.4	0.3	0.4	0.5	0.9	1.2	0.4
0.1	0.3	0.5	0.3	0.3	0.3	0.3	0.5	0.8	0.1	0.2	0.2	0.3	0.4	0.5	1.1	0.8	0.2
0.0	0.2	0.6	0.6	0.3	0.4	0.4	0.4	0.5	0.0	0.1	0.2	0.3	0.3	0.7	0.9	0.4	0.0
0.0	0.1	0.4	0.8	0.7	0.5	0.5	0.6	0.7	0.0	0.1	0.2	0.3	0.6	0.8	0.5	0.1	0.0
0.0	0.0	0.1	0.5	0.9	1.1	0.9	0.7	0.7	0.0	0.1	0.3	0.5	0.6	0.4	0.1	0.0	0.0
0.0	0.0	0.0	0.1	0.4	0.8	1.2	1.4	1.5	0.1	0.2	0.3	0.3	0.2	0.1	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.7	0.9	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

Plate. 1. HEDIA and CATCH3D models interfaces for output sprinkler water distribution patterns from the four radials data inputs.

As demonstrated in table (3) of input radials.

In plate (1) of HEDIA simulated sprinkler water distribution pattern from the four radials data affecting on the angle of part sector and the data in each part sector. Developed model radial technique depend on spline data on each radials data, then institute spline circles includes all effects of radials data at a distance of the circles radius so by part angle location of any point on specific circle, model generate its magnitude. For that part sector which the two radials data equal zero was appeared in part number three with separation angle of 90^{o}. On the other hand part sector number one with the two equal radials magnitude generate equilibrium part sector data. Data in part sector number two sprinkler water distribution pattern. Finally it appeared that, radial technique in HEDIA computer model more accurate than CATCH3D model in simulating sprinkler water distribution pattern.

Table 4. Six radials data input as in filed test.

	Can1	Can2	Can3	Can4	Can5	Can6	Can7	Can8	Can9
Radial 1	2.6	2.2	1.4	0.9	0.5	0.7	0.7	1.6	1.9
Radial 2	2.6	2.2	1.4	0.9	0.5	0.7	0.7	1.6	1.9
Radial 3	0	0	0	0	0	0	0	0	0
Radial 4	0	0	0	0	0	0	0	0	0
Radial 5	2.6	2.2	1.4	0.9	0.5	0.7	0.7	1.6	1.9
Radial 6	2.6	2.2	1.4	0.9	0.5	0.7	0.7	1.6	1.9

HEDIA computer model

0	0	0	0	0	0	0.24	0.43	0.61	0.71	0.7	0.56	0	0	0	0	0	0
0	0	0	0	0	0.2	0.58	0.87	1.07	1.27	1.52	1.62	1.29	0.7	0	0	0	0
0	0	0	0	0	0.08	0.22	0.33	0.46	0.56	0.64	0.78	1.4	1.7	0.9	0	0	0
0	0	0	0	0	0	0.15	0.34	0.45	0.57	0.74	0.89	0.7	1	1.7	0.9	0	0
0	0	0	0	0	0	0.02	0.14	0.31	0.42	0.38	0.5	0.8	0.8	1	1.7	0.7	0
0	0	0	0	0	0	0	0.17	0.53	0.77	0.79	0.6	0.4	0.8	0.7	1.4	1.3	0
0	0	0	0	0	0	0	0	0.72	1.25	1.1	0.9	0.6	0.5	0.9	0.8	1.7	0.6
0	0	0	0	0	0	0	0	0.75	2.1	1.8	1.1	0.8	0.4	0.8	0.7	1.7	0.8
0	0	0	0	0	0	0	0	0	2.5	2.2	1.4	0.9	0.5	0.7	0.7	1.6	0.9
0.01	0.03	0.01	0.02	0.01	0.04	0.09	0.3	1.5	2.41	2.11	1.36	0.88	0.49	0.69	0.69	1.58	0.89
0.04	0.11	0.06	0.08	0.05	0.16	0.35	1.08	2.54	2.54	1.73	1.05	0.76	0.38	0.77	0.68	1.65	0.78
0.07	0.23	0.13	0.19	0.14	0.24	0.54	1.07	1.7	1.7	1.1	0.87	0.57	0.48	0.86	0.76	1.63	0.58
0	0.29	0.38	0.24	0.36	0.24	0.5	0.88	1.11	1.11	0.88	0.59	0.39	0.76	0.67	1.33	1.24	0
0	0.22	0.65	0.47	0.48	0.62	0.51	0.46	0.62	0.62	0.46	0.51	0.78	0.77	0.96	1.62	0.67	0
0	0	0.44	1.02	0.74	0.65	0.98	0.95	0.87	0.87	0.95	0.98	0.69	0.97	1.64	0.86	0	0
0	0	0	0.64	1.47	1.44	0.9	0.84	0.87	0.87	0.84	0.9	1.44	1.68	0.88	0	0	0
0	0	0	0	0.68	1.4	1.96	2.06	1.99	1.99	2.06	1.96	1.4	0.7	0	0	0	0
0	0	0	0	0	0	0.71	0.98	1.12	1.12	0.98	0.71	0	0	0	0	0	0

CATCH3D computer model

0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.9	0.9	0.8	0.5	0.2	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	1.1	1.5	1.6	1.6	1.6	1.6	1.5	1.1	0.7	0.1	0.0	0.0	0.0
0.0	0.0	0.1	0.2	0.1	1.5	1.2	0.8	0.7	0.7	0.8	1.2	1.5	1.5	0.9	0.2	0.0	0.0
0.0	0.1	0.3	0.4	0.2	0.0	0.6	0.7	0.7	0.7	0.7	0.6	0.7	1.3	1.5	0.9	0.1	0.0
0.0	0.3	0.6	0.5	0.2	0.1	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.7	1.3	1.5	0.7	0.0
0.1	0.7	0.8	0.3	0.3	0.1	0.0	0.7	0.9	0.9	0.7	0.5	0.6	0.7	0.7	1.5	1.1	0.2
0.4	1.0	0.8	0.4	0.3	0.2	0.2	0.0	1.4	1.4	1.2	0.9	0.5	0.6	0.6	1.2	1.5	0.5
0.6	1.3	0.7	0.5	0.4	0.5	0.6	0.4	2.1	2.1	1.7	1.2	0.7	0.5	0.7	0.8	1.6	0.8
0.8	1.5	0.7	0.6	0.4	0.8	1.1	1.5	0.6	2.7	2.1	1.4	0.9	0.5	0.7	0.7	1.6	0.9
0.0	0.1	0.1	0.1	0.1	0.1	0.3	0.7	2.0	2.7	2.1	1.4	0.9	0.5	0.7	0.7	1.6	0.9
0.1	0.3	0.2	0.2	0.2	0.3	0.6	1.3	2.1	2.1	1.7	1.2	0.7	0.5	0.7	0.8	1.6	0.8
0.1	0.4	0.4	0.3	0.3	0.3	0.7	1.1	1.4	1.4	1.2	0.9	0.5	0.6	0.6	1.2	1.5	0.5
0.1	0.5	0.7	0.4	0.4	0.4	0.5	0.7	0.9	0.9	0.7	0.5	0.6	0.7	0.7	1.5	1.1	0.2
0.0	0.3	0.8	0.9	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.7	1.3	1.5	0.7	0.0
0.0	0.1	0.6	1.2	1.1	0.7	0.6	0.7	0.7	0.7	0.7	0.6	0.7	1.3	1.5	0.9	0.1	0.0
0.0	0.0	0.2	0.7	1.3	1.5	1.2	0.8	0.7	0.7	0.8	1.2	1.5	1.5	0.9	0.2	0.0	0.0
0.0	0.0	0.0	0.1	0.6	1.1	1.5	1.6	1.6	1.6	1.6	1.5	1.1	0.7	0.1	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.9	0.9	0.8	0.5	0.2	0.0	0.0	0.0	0.0	0.0

Plate. 2. HEDIA and CATCH3D models interfaces for output sprinkler water distribution patterns from the six radials data inputs.

Conclusion

Verification of HEDIA computer model using CATCH3D model substantiated the accurately simulation of HEDIA model than CATCH3D. The following points summarize the verification main results:

- ✓ HEDIA model more accurate than CATCH3D in simulating several numbers of radials data and in simulating even triangle sprinklers overlapping pattern shape.
- ✓ For sprinklers overlapping patterns mean water application depths and Christiansen uniformity coefficient, HEDIA and CATCH3D output results more correlated to each other when neglecting CATCH3D insufficient results in even triangle overlapping patterns with acceptably range of MAE.

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تقييم وتحقق صحة استخدام نموذج هديه الحاسوبي لتصميم تداخل الرشاشات

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تستخدم أنظمة الري بالرش على مستوى العالم باعتبارها واحدة من تقنيات الري الضغطي الرئيسة الموفرة للمياه، نظرًا لملائمتها لنطاق واسع من الزرعات وسهولة التشغيل الآلي لها. ويعد كفاءة اضافة المياة وتجانس توزيعها مؤشرًا مهمًا في تقييم جودة تصميم نظام الري وبالتالى جودة الإنتاج الزراعي. لذا تم اعداد برنامج HEDIA لاختيار التصميم الأكثر قبولًا لنمط التداخل الهندسي للرشاشات اعتمادًا على معامل التوزيع Christiansen وباستخدام تقنية تداخل الرشاش Superimposition Technique وطريقة الاشتقاق بنظام الشرائح التكعيبية Double Cubic Spline Interpolation Method في توليد بيانات نمط توزيع المياه المتداخلة بين الرشاشات بدلالة بيانات توزيع المياة لرشاش واحد فعليا تحت الظروف التشغيلية المختارة سواء حقليا أو معمليًا. وتم التحقق من صحة نتائج البرنامج HEDIA بمعايرة نتائجة معمليا كما تم تقييم نتائجة بواسطة برنامج CATCH3D-٤,٦ وأشارت النتائج إلى أن برنامج CATCH3D-4.6 لا يمكنه حساب بيانات تجيع المياه بدقة في منطقة تداخل الرشاشات ذات نمط التداخل المثلثى وعدم قدرتة على التنبؤ بنمط توزيع مياه الرش من بيانات المياة لأنصاف أقطار متعددة "شعاعية" بخلاف برنامج HEDIA والذي أمكنه محكاة البيانات الفعلية بمعامل ارتباط عالى التأثير سواء لمدخلات بيانات المياة التى تتبع التوزيع الشبكى أو الشعاعي. لذا يمكن القول أن برنامج HEDIA يمكنه محكاة توزيع المياة لرشاشات متداخلة هندسيا بأنماط وأبعاد مختلفة وحساب كفاءة توزيع المياة لها من خلال مدخلات توزيع المياة الشبكية او الشعاعية للرشاش والتى من خلالها يتم إنشاء بيانات نمط توزيع المياة للرشاش ثم تطبيق حسابات الأنماط المتداخلة بشكل مباشر للوصول الى افضل تداخل تصميمى. لذا يمكن القول بأن برنامج HEDIA يعتبر بمثابة نموذج حاسوبى تصميمى يمكنه إعطاء أنسب التصميمات الهندسية لتوزيع الرشاشات الحقلية تحت ظروف التشغيل الفعلية للوصول إلى أعلى انتظامية لتوزيع المياه.