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Dynamic Simulation Model of Channel Leakage Based on Multiple Regression

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Abstract: Aiming at the problem that the existing channel leakage calculation methods generally ignore the dynamic changes of influencing factors, which leads to a large calculation error, this study attempts to utilize the machine learning method to accurately calculate the channel leakage loss under the dynamic changes in the influencing factors. By using the machine learning method to analyze the impact of dynamic changes in the flow rate and soil moisture content over time on the channel leakage loss in the water transmission process and quantify the impact of the selected factors on the leakage loss, a dynamic simulation model of the multi-parameter channel leakage loss was constructed, and a test was carried out in the irrigation area to verify the accuracy of the model. The test results are as follows: the actual leakage loss of the U1 channel is 1094.03 m^3, the simulated value of the model is the 1005.24 m^3, and the error between the simulated value and the measured value is 8.12%; the total leakage of the U2 channel is 1111.24 m^3, the simulated value of the model is 1021.1 m^3, and the error between the simulated value and the measured value is 6.31%. The experimental results show that the use of machine learning to construct a dynamic simulation model of channel leakage loss under the comprehensive consideration of the dynamic change in influencing factors over time has a better effect, and the calculation accuracy is high.

Keywords: channel; leakage loss; machine learning; multifactor; leakage test

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Citation: Ma, J.; Yang, J.; Hao, X.; Cui, B.; Yang, S. Dynamic Simulation Model of Channel Leakage Based on Multiple Regression. *Sustainability* **2023**, *15*, 14904. https://doi.org/10.3390/su152014904

Academic Editor: Andrea G. Capodaglio

Received: 19 August 2023
Revised: 28 September 2023
Accepted: 12 October 2023
Published: 16 October 2023

1. Introduction

At present, the contradiction of water use in China's irrigation areas is becoming more and more acute, and problems such as serious waste of irrigation water resources and low utilization efficiency still exist. According to statistics in 2020, the water utilization coefficient of the backbone canal system in China's large irrigation districts was only 0.643 [1]. It has been shown that leakage from canals at the dry and branch levels is an important cause of irrigation water losses during the irrigation process [2]. Because the channel leakage rate is affected by flow rate, water depth, wetted perimeter, channel length, lining conditions, soil factor, water transfer time and other factors, and the current practice of using various types of empirical formulas to estimate the leakage loss of different types of channels, but the empirical formulas are generally only selected flow rate, depth of water, wet week, and flow rate of one or more influencing factors as a variable to calculate the leakage amount of the channel. Considering fewer factors and ignoring the dynamic changes of each factor over time, this leads to a large error between the results of empirical formulas and the actual leakage loss, which affects the accurate management of water resources in irrigation districts. Therefore, it is of great significance to construct a multi-parameter dynamic formula for calculating the channel leakage rate to accurately calculate the channel leakage loss and to strengthen the strict management of water resources in irrigation districts in China.

The research methods of channel leakage loss mainly focus on empirical formulas, numerical simulation [3], and two aspects. In the research of empirical formulas of channel leakage, foreign scholars put forward a variety of empirical formulas, including the Davis-Wilson formula, Kosgakov formula, etc., where the Davis-Wilson formula, which uses the wetted perimeter of the channel, water level, and flow rate as variables, is mostly used to calculate channels with liners. However, Kausgakov's formula, which uses flow and soil as variables, is mostly used to make calculations for leakage in earthen channels [4–7]; due to the simplicity and ease of use of empirical formulas, various types of empirical formulas are generally used in practice nowadays to calculate leakage loss losses [8–11]. However, the empirical formulas generally use only one or several channel physical properties and different permeability coefficients as variables for calculation, with fewer factors to consider and poorer calculation accuracy. Shah et al. [9] and Zhang et al. [10] showed that the calculated values of Kausgakov's formula were 1.5- and 2.5-times higher than the actual values, and Akkuzu found that the leakage losses estimated by Moritz's and Davidson-Wilson formulas are much lower than the measured values [11], The empirical formula has been improved by some scholars in China. Men Baohui [12] and others improved the empirical formulas by using the method of integration; Xie Chongbao [13] and others combined different empirical formulas to propose improved empirical formulas that are related to both channel cross-section size and soil type; Wang Bingchuan [14] et al. derived the improved formula by integrating Korsgakov's formula. It is found that the numerical simulation method to calculate the leakage loss of the channel has a better effect, and the object of the study can be either the whole channel or part of the channel section, which has a wider range of applications. The use of computer programming calculations can be quickly obtained as results, the calculation accuracy is higher than the empirical formula, intuition, better expandability than the field test, easy to understand, and later analysis. In the numerical simulation study of channel leakage loss, Zhang Fan [15] et al. proposed a method for estimating channel leakage loss by using a statistical method. The established numerical simulation model is about 10% more accurate than traditional leakage calculation methods. Liao Xiangcheng [16] et al. introduced the concept of pre-influence water content of channel soil, and they proposed a method for calculating the permeability coefficient and index of the soil of the canal bed. By improving the calculation formula, the leakage loss calculation error was reduced to less than 20%. At present, most of the research on channel leakage loss stays in static calculation, and the way and degree of influence of the dynamic changes of each influencing factor on the channel leakage loss have not been clarified, which affects the precise control of the channel water transfer process in irrigation districts.

In this study, we attempted to use a machine learning method to calculate the channel leakage loss under the dynamic change of influencing factors by constructing a dynamic simulation model of multi-parameter channel leakage loss. In this study, we will quantify the influence of each influential factor on leakage loss by comprehensively considering the dynamic changes of some factors in the channel water delivery process, compare with the empirical formulas by constructing a machine learning model, and further explore the changes of channel leakage loss in different time periods by combining numerical simulation and field tests in a long time series, and the results of this study will help the irrigation district to clarify the leakage status of each channel and provide a basis for realizing precise control of channel water transfer.

2. Materials and Methods

2.1. Research Area

Wharf irrigation area district is located in the southeast of Linyi City, Shandong Province (Figure 1). The designed irrigation area is 19,667 hectares, belonging to the temperate monsoon zone of semi-humid transitional climate. The average annual temperature of the irrigation area is 13.3 °C, the annual sunshine hours are 2460 h, and the average rainfall is 840.3 mm per year. The main crops are wheat, rice, corn, and peanuts. There are 3 trunk canals and 24 branch canals in the irrigation area, and the types of canals are unlined earth canals, among which there are 12 branch canals under the first trunk canal, controlling the irrigated area of 13,367 hectares. There are 8 branch canals under the second trunk canal, controlling an irrigated area of 4633 hectares, and there are 4 branch canals under the third trunk canal, controlling an irrigated area of 1667 hectares. The irrigation district canal system project was built a long time ago. The aging and degradation problem is serious, a lot of the canal section channel has collapsed, siltation is present, channel water transfer capacity is seriously insufficient, irrigation water utilization coefficient is only 0.44 or so, and irrigation water resources are seriously wasted.

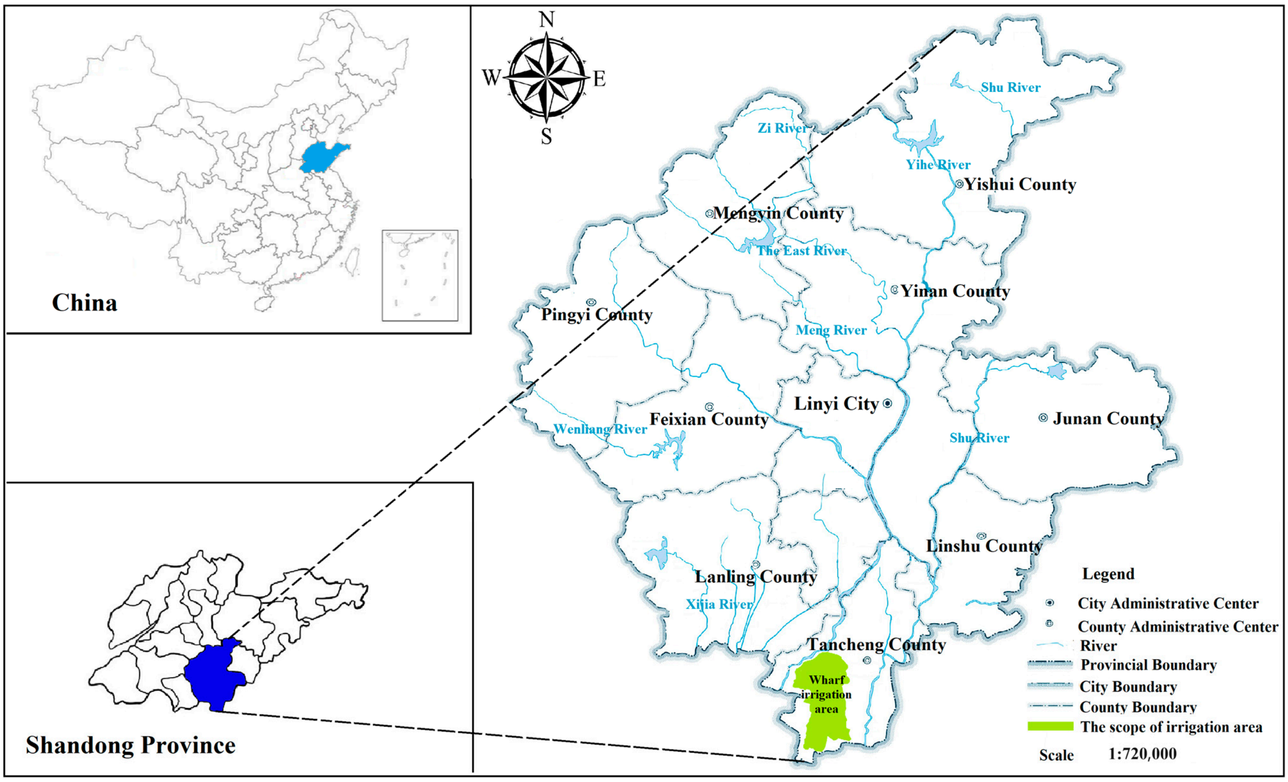


Figure 1. Geographical location of irrigation district.

2.2. Pilot Program

In this study, two sections of channels with pile numbers 7 + 320 to 8 + 520 and 14 + 070 to 15 + 270 were selected as test channels for dynamic simulation of seepage loss in 1 main canal. Among them, the design flow rate of the channel in the section from pile No. 7 + 320 to 8 + 520 is 14.7 m^3/s, the soil type is medium loam with average permeability, and the design flow rate of the channel in the section from pile No. 14 + 070 to 15 + 270 is 13.9 m^3/s, and the soil type is light loam with high permeability. Both sections of the channel are 1 km long, trapezoidal cross-section unlined earth channels; the bottom of the channel is relatively flat, and the length of the channel meets the requirements of the test. Detailed information of the test channel is shown in Table 1. The object of this study is the channel as a whole, without distinguishing the differences between the various segments of the channel, and we only need to measure the leakage loss of the test channel as a whole, so the test selected the dynamic water method to measure the real leakage loss of the channel, through the channel to the test channel, and measure the upstream and downstream flow rate loss within a specified period of time to calculate the actual leakage loss of the channel, and the actual leakage loss of the channel is calculated. This test was set up in the upstream and downstream speed measurement section 8 speed lines, with speed measurement method using the five-point method. Five points were set up near the water surface, 0.2-times the lateral water depth, 0.6-times the lateral water depth, and 0.8-times the lateral water depth. Near the bed of the canal, the length of the flow velocity meter speed measurement was set to 80 s, the test lasted for 15 h of water conveyance, and the measurement interval was 1 h.

Table 1. Detailed information of experimental channels.

Channel Number	Length (m)	Bottom Width (m)	Superelevation (m)	Flow Velocity (m^3/s)	Designed Discharge (m^3/s)	Soil Texture	Water Permeability	Roughness Factor	Gradient	Cross-Section Form
U1	1000	6	0.5	0.852	14.7	medium frequency transformer loam	general	0.02	1/5000	trapezium
U2	1000	6	0.5	0.827	13.9	light flux loam	strong	0.02	1/5000	trapezium

2.3. Data Sources

2.3.1. Soil Data

The soil medium is defined as the soil present in the uppermost layer of the ground. The top weathered portion of the unsaturated zone with substantial biological activity is represented by the soil medium [17]. It has been shown that different soils have different permeability [18,19], and for more clay-heavy soils, the smaller the pore space between the soil particles, the coarser the soil texture; the larger the pores between the soil particles, the stronger the gravitational force on the soil, and the greater the rate of soil leakage [20]. The soil in the irrigation area is mostly sandy loam, with soil particle sizes ranging from 0.02 mm to 0.2 mm, with soil pore ratios ranging from 0.79 to 0.87, vertical permeability coefficients ranging from 0.00019 to 0.00026, and sand content, percolation losses, water retention, and aeration properties being relatively average. The data were obtained from the local irrigation district administration.

2.3.2. Channel Data

Channel data were obtained from local irrigation district authorities (Table 2).

Table 2. Irrigation district channel information.

Name of Branch Canal	Length (m)	Cross-Section Form	Bottom Width (m)	Depth (m)
No.1 branch canal	7320	trapezium	6	0.5
No.2 branch canal	3270	trapezium	6	0.5
No.3 branch canal	2250	trapezium	6	0.5
No.4 branch canal	1100	trapezium	6	0.5
No.5 branch canal	60	trapezium	6	0.5
No.6 branch canal	4550	trapezium	6	0.5
No.7 branch canal	3930	trapezium	6	0.5
No.8 branch canal	1250	trapezium	6	0.5
No.9 branch canal	100	trapezium	6	0.5
No.10 branch canal	2640	trapezium	5	0.5
No.11 branch canal	10	trapezium	5	0.5
No.12 branch canal	470	trapezium	5	0.5

2.4. Model Building

Meta-regression is a statistical method based on mathematical statistics to find an approximate mathematical expression to describe the correlation between several variables. The establishment process includes three parts: regression factor correlation analysis, model establishment, and goodness-of-fit test. The regression model of random variable Y and general variable X can be expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \tag{1}$$

In the formula, β_0 is a constant term; $\beta_1, \beta_2, \ldots \beta_k$ are regression coefficients; Y is the dependent variable; $X_1, X_2, \ldots X_k$ are k precisely measurable independent variables.

Correlation analysis is used to determine whether there is a relationship between two or more variable elements, the form of expression of the correlation relationship, the closeness, and the direction of the correlation relationship. It is a method for analyzing causal variables and expressing them with indicators.

$$r_{xy} = \frac{S_{xy}}{S_x S_y} \tag{2}$$

In the formula, r_{xy} is the sample correlation coefficient; S_{xy} is the sample covariance; S_x is the sample standard deviation of X; S_y is the sample standard deviation of y.

The goodness of fit of the model can be tested using the adjusted coefficient of determination $\overline{R^2}$:

$$R^2 = \frac{SSR}{SST} = \frac{SST - SSE}{SST} \tag{3}$$

$$\overline{R^2} = 1 - \frac{\frac{SSR}{n-k-1}}{\frac{SST}{n-1}} = 1 - R^2 \times \left(\frac{n-1}{n-k-1}\right) \tag{4}$$

In the formula, R^2 is the sample determinable coefficient; $\overline{R^2}$ is the adjusted coefficient of determination; SST is the sum of square of total deviation; SSR is the sum of regression squares; SSE is the sum of squared residuals; the value of the coefficient $\overline{R^2}$ is $0 \leq \overline{R^2} \leq 1$. The closer the R^2 value is to 1, the higher the goodness of fit of the equation, and the better the model effect.

2.4.1. Correlation Analysis of Influencing Factors

In the actual water conveyance process, factors, including soil factors, channel characteristics, lining conditions, nature of lining materials [21], groundwater, time factors, specific physical methods [22], and other factors, will have an impact on the channel leakage loss, and these factors are related to each other, interact with each other, and it is difficult to make a clear distinction in practice [23]. Figure 2 shows the results of the correlation analysis of leakage influencing factors selected in this study.

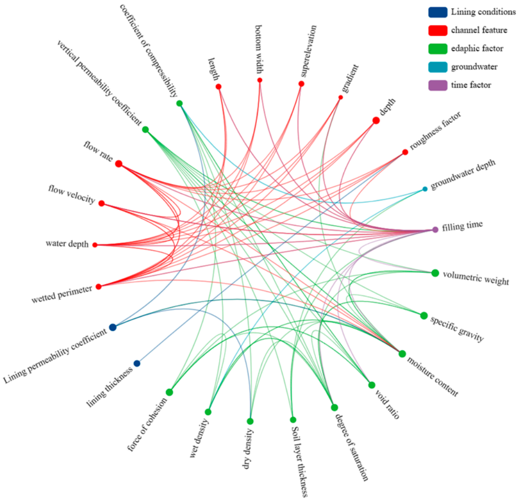


Figure 2. Influencing factors of channel leakage.

In this study, based on the existing channel water transmission data in the irrigation area, the physical properties of the channel were analyzed and selected to include five factors, namely, channel length, bottom width, superelevation, gradient, and roughness. The hydraulic properties included three factors, namely, water level, flow rate, and groundwater level. The soil factors were selected to include three factors, namely, void ratio of the soil, vertical permeability coefficient, and soil water content, with a total of eleven factors to be analyzed in the correlation analysis. The results of the bivariate Pearson test for correlation between factors are shown in Figure 3. The results of correlation analysis show that, except for the two factors of channel length and bottom width, all other factors have strong correlation with seepage loss, so multiple regression analysis can be carried out.

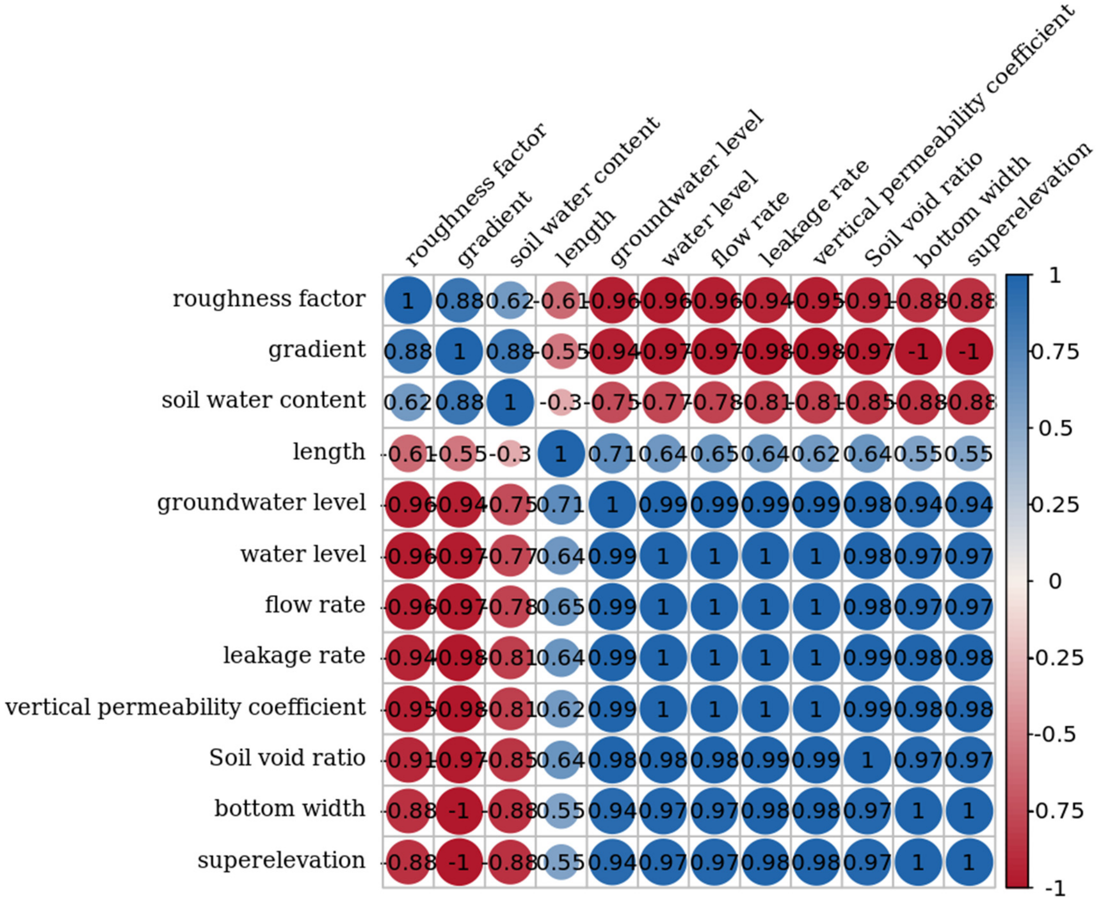


Figure 3. Correlation analysis.

2.4.2. Dynamic Simulation Model of Channel Leakage Rate Based on Multiple Regression

Table 3 shows an attempt to model multiple regressions based on available channel water delivery data. In a multiple regression model, the magnitude of the regression coefficient indicates the magnitude of the effect of the factor on the regressed factor, i.e., the degree of sensitivity of the factor. After analyzing model 3 through the test factor containing channel physical conditions, water factor, and soil moisture, three parts of the factors, in line with the requirements of the selection of factors in this study, selecting the factors with significance less than 0.05, can be seen. The vertical seepage loss coefficient has the greatest impact on seepage loss, the regression coefficient of 89.54, followed by the gradient, roughness factor, the soil void ratio, soil water content, water level, groundwater level, the flow rate, and regression coefficients (46.1030, 0.7470, −0.0370, −0.0320, 0.0070, −0.0010, and 0.0004, respectively). Therefore, in this study, the optimal linear regression equation was established with the channel leakage loss (Y) as the dependent variable, and gradient, roughness factor, water level, flow rate, groundwater level, soil void ratio, vertical permeability coefficient, and soil water content as the regressor as follows: $Y = -0.004 + 89.54X_0 + 46.103X_1 + 0.747X_2 - 0.037X_3 - 0.032X_4 + 0.007X_5 - 0.001X_6 + 0.0004X_7$.

Table 3. Multiple standard regression analysis of channel leakage rate and its influencing factors.

Model		Non-Standardized Coefficient		Standardized Coefficient	t	Significance
		B	STDERR	Beat		
1	(constant)	0.011	0.368	-	28.682	0.689
	length	3.14×10^{-5}	0.598	0.037	0.366	0.723
	flow rate	0	0.211	0.944	9.25	0.587
	soil water content	0.219	0.109	0.293	2.017	0.083
	water level	0.015	0.852	0.188	0.124	0.006
2	(constant)	0.009	0.027	-	0.343	0.764
	length	5.02×10^{-4}	0.397	−0.06	−0.399	0.728
	superelevation	−0.034	0.029	−0.808	−1.188	0.357
	roughness factor	0.47	0.259	0.627	1.816	0.211
	drawdown	−0.023	0.246	−0.032	−0.095	0.933
	flow rate	0.001	0.514	1.603	2.027	0.18
3	(constant)	−0.004	0.01	-	−0.355	0.029
	length	2.54×10^{-4}	0.652	−0.03	−0.273	0.83
	gradient	46.103	22.298	1.081	2.068	0.047
	roughness factor	0.747	0.252	0.997	2.963	0.039
	water level	0.007	0.004	1.138	1.66	0.031
	flow rate	0.0004	0.323	0.847	1.152	0.014
	groundwater level	−0.001	0.981	−0.178	−1.027	0.048
	soil void ratio	−0.037	0.028	−0.557	−1.303	0.028
	vertical permeability coefficient	89.54	41.917	1.218	2.136	0.020
	soil water content	−0.032	0.019	−0.292	−1.652	0.033

3. Results

3.1. Parametric Simulation Results

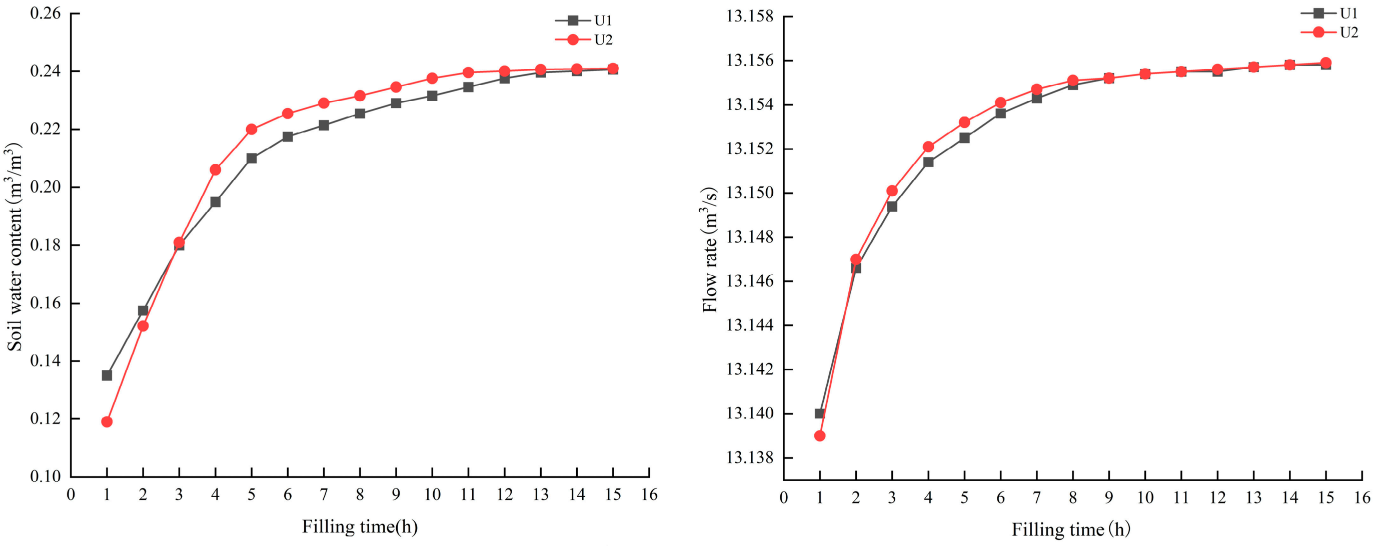
The reliability of the developed multiple regression model was verified and tested for significance using SPSS 27 software, and Table 4 shows the model test table. From Table 4, the adjusted R^2 is 0.982, and the model Durbin–Watson coefficient is 2.732, which indicates that the model has a good regression effect.

Table 4. Model verification.

Model Summary					
Model	R	R^2	Adjusted R^2	Errors in Standard Estimates	Debin-Watson Coefficient
1	0.999	0.998	0.982	0.000262	2.732

3.2. Experimental Validation

In the actual water transfer process, the two factors of channel flow and soil water content have the characteristics of changing with the change in the water transfer time. This leads to the fact that ignoring the dynamic characteristics of channel leakage losses in the calculation can lead to a large error between the calculation results and the actual leakage rate. Figure 4 shows the flow rate in the channel during the test period measured using the flow meter and the soil moisture content from 10 cm to 20 cm in the channel measured via the real-time monitoring system in the field. The analysis shows that soil water content and flow rate change significantly with water delivery time in the two test channels. The flow varied between 13.14–13.158 $m^3 \cdot s^{-1}$ and 13.139–13.156 $m^3 \cdot s^{-1}$, and the soil water content varied between 0.135–0.241 $m^3 \cdot m^{-3}$ and 0.119–0.24 $m^3 \cdot m^{-3}$, respectively. The results of this measurement are consistent with the results of a study by Ruixuan Li [24] et al.

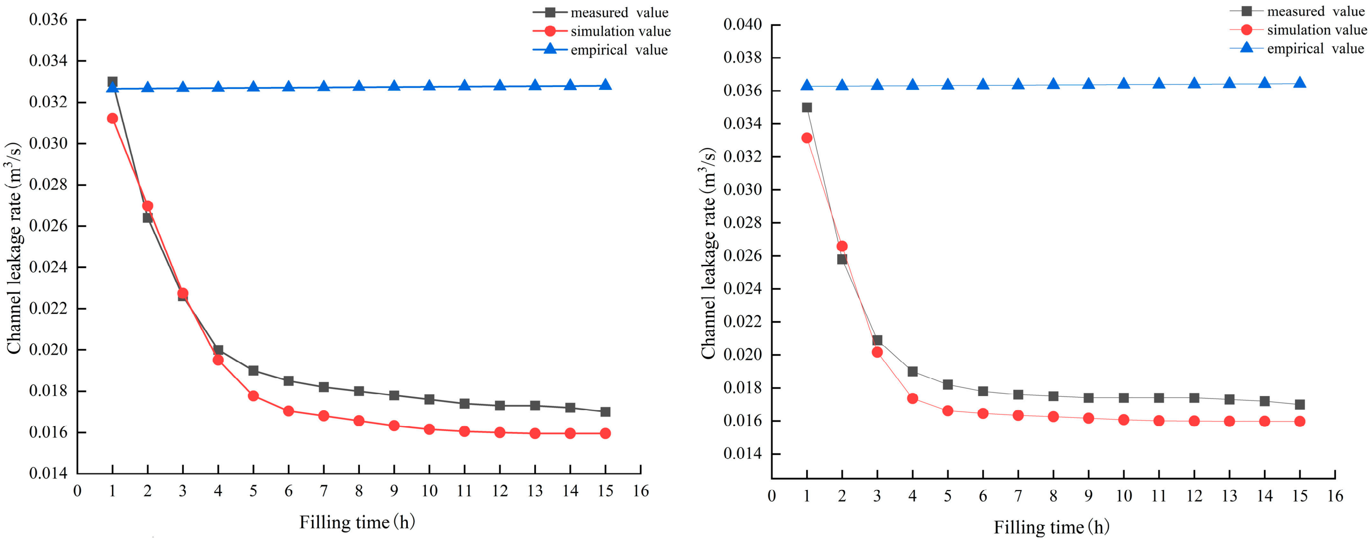


(a) (b)

Figure 4. Dynamic monitoring of selected factors: (**a**) dynamic monitoring of soil water content; (**b**) dynamic monitoring of flow.

3.2.1. Dynamic Simulation of Channel Leakage Rate

The data on gradient, roughness, flow rate, and soil moisture content are brought into the regression model to calculate the simulated value of the seepage rate. The actual leakage rate of the test channel was measured using the dynamic water method. In addition, in order to verify the accuracy of the model, the Kausgakov empirical formula to calculate the channel leakage loss was selected as a comparison, and the comparison of the actual leakage rate, the model simulation value, and the calculated value of the empirical formula is shown in Figure 5.



(a) (b)

Figure 5. Dynamic simulation of leakage rate: (**a**) dynamic simulation of leakage rate in channel U1; (**b**) dynamic simulation of leakage rate in channel U2.

From the results of the calculations, it is clear that there is a large difference between the channel leakage rates calculated using model simulations and empirical formulas, Kausgakov's empirical formula for calculating seepage rate using soil permeability parameters, soil permeability index, and flow rate. Due to the empirical formulas consideration of fewer factors and ignoring the dynamic changes in the influencing factors, the result was the calculation of its results and the actual leakage rate, being closer only at the beginning of the water transfer. Afterwards, with the increase in the water transmission time, some of the factors affecting leakage change dynamically, and the error between the calculated value of the empirical formula and the actual leakage rate becomes bigger gradually. At the beginning of water transfer U1, the U2 channel empirical formula seepage rate calculation value and the actual seepage rate error are only 1.01% and 3.66%. After that, with the increase in the water transmission time, some of the factors affecting leakage change dynamically, and the error between the calculated value of the empirical formula and the actual leakage rate gradually becomes larger; the error reaches 92.98% and 114.31% at 15 h.

The model simulation value and the actual seepage rate change trend are more consistent. They are presented in the early stage of water transmission seepage rate with a rapid decrease, slowly declining in the middle of the seepage rate and gradually tending to stabilize the change trend. The leakage rate of the U1 channel decreases rapidly from 1 h to 5 h, and after 5 h, the leakage rate decreases gradually and finally reaches a steady seepage state around 10 h. The average relative error between the simulated and measured values was 6.45%. The U2 channel shows a faster decreasing trend in terms of the change in seepage rate than the U1 channel in 1–4 h due to better soil permeability. The seepage loss gradually decreases after 4 h and finally reaches a steady seepage state around 7 h, and the average relative error between the simulated and measured values is 7.04%.

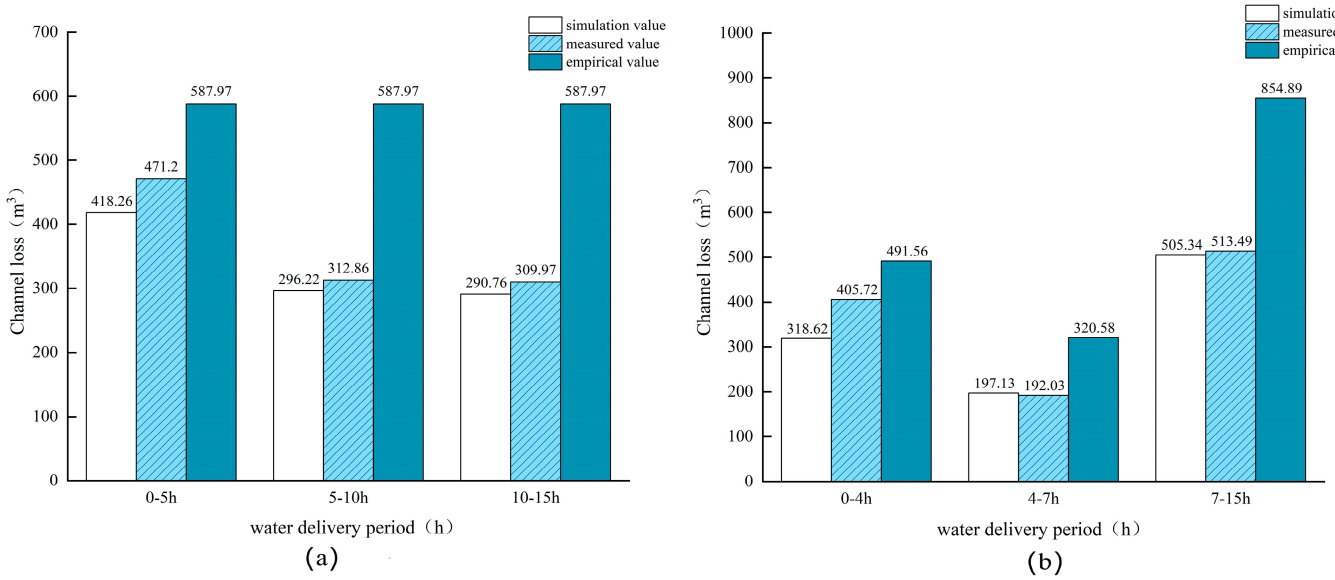
3.2.2. Leakage Loss Simulation

Based on the dynamic simulation model of channel leakage rate, the regression equation was transformed by fitting the flow rate and soil water content elements into a function about time t using the data fitting method. Using SPSS software to fit the data to the flow rate and soil moisture content gives the fitted equation for soil moisture content in channel U1 as follows: $I1 = 0.162 + 0.0315t - 0.0027t^2 + 0.000078079t^3$. The equation fitted to the soil water content of channel U2 is $I2 = 0.0794 + 0.0452t - 0.0042t^2 + 0.00013092t^3$, where I is the soil water content and t is the water delivery time. The U1 channel flow fitting equation is as follows: $Z1 = 13.1362 + 0.0056t - 0.00053505t^2 + 0.000016834t^3$. The U2 channel flow fitting equation is $Z2 = 13.1349 + 0.0065t - 0.00066221t^2 + 0.000021699t^3$, where Z is the channel flow and t is the water delivery time.

Bringing the fitted equation into the U1 channel leakage loss multiple regression equation transforms the regression equation into $Y1 = 0.02014048 + 0.00100576 + 0.000086186t^2 - 0.00000249179t^3$. The multiple regression equation for U2 channel leakage loss can be transformed into $Y2 = 0.02278316 + 0.0014438t + 0.000134135t^2 - 0.00000418076t^3$, where Y is the channel leakage rate and t is the water delivery time.

Establishing the integral model, the data will be brought into the calculation and can be obtained after the model simulation value, the model simulation value, and empirical formula calculated value. The actual leakage loss comparison is shown in Figures 6 and 7.

From the simulation results, it is clear that the simulated value of U1 channel leakage in 1–5 h is 328.8 m^3, and the actual leakage loss is 471.2 m^3; the error of both is 30.22%. The Kausgakov empirical formula results in 587.97 m^3, which is 24.78% error from the actual leakage loss. In 5–10 h, the leakage simulation value is 296.22 m^3, the actual leakage loss is 312.86 m^3, and the error of both is 5.32%. The Kausgakov empirical formula calculates the result as 587.97 m^3, and the actual leakage loss error is 87.93%. At the end of the 10–15 h, the leakage simulation value is 290.76 m^3, the actual leakage loss is 309.97 m^3, and the error of both is 6.2%. The Kausgakov empirical formula calculated results for 587.97 m^3, and the actual leakage loss error is 89.69%. The U2 channel in the 1–4 h leakage simulation value is 295.83 m^3, the actual leakage loss ois425.72 m^3, and the error of the two is 27.8%. The Kausgakov empirical formula calculated results for 491.56 m^3, and the actual leakage loss error is 21.16%. In 4–7 h, the leakage simulation value is 197.14 m^3, the actual leakage loss is 192.03 m^3, and the error of the two is 2.66%. The Kausgakov empirical formula calculates the results as 320.58 m^3, and the actual leakage loss is 66.94% error. At the end of 7–15 h, the leakage simulation value is 505.34 m^3, the actual leakage loss is 513.49 m^3, and the error of both is 1.59%. The Kausgakov empirical formula calculates 854.89 m^3, and the actual leakage loss error is 66.49%. From the simulation results, it can be seen that the established model has a good effect on the simulation of seepage loss in all seepage stages of the channel.



(a)

(b)

Figure 6. Dynamic simulation of leakage at various stages: (**a**) dynamic simulation of leakage in channel U1; (**b**) dynamic simulation of leakage in channel U2.

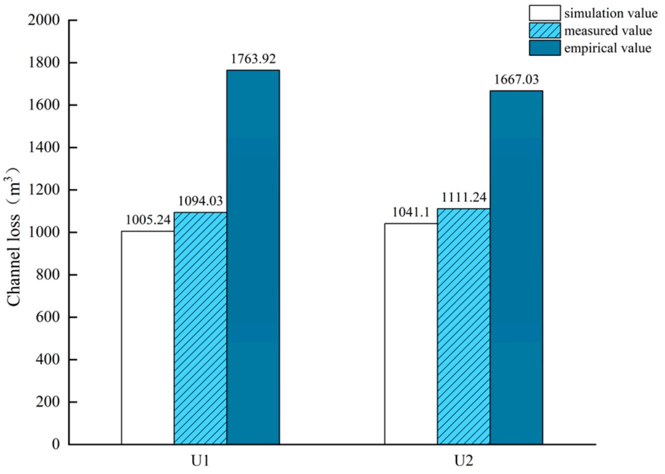


Figure 7. Comparison of total leakage.

During the test period, the total actual leakage of the U1 channel was 1094.03 m^3, the model simulation value was 1005.24 m^3, and the value calculated using the Kausgakov empirical formula was 1763.92 m^3. The error between the simulated and measured values was 8.12%, while the error between the empirical and measured values was 61.23%. The total amount of actual leakage of the U2 channel was 1111.24 m^3, the model simulation value was 1021.1 m^3, and the value calculated using the Korsgakov empirical formula was 1667.03 m^3. The error between the simulated value and measured value was 6.31%, while the error between the empirical value and measured value was 50.02%, and compared with the measured value, the model simulation value was more accurate than the result of the empirical formula calculation.

4. Discussion

The following results were obtained according to the research objectives set at the beginning of this study. On the one hand, the regression results showed that the vertical seepage velocity coefficient and soil pore ratio had a greater influence on the calculation of channel seepage loss, and both factors belonged to soil properties, which indicated that the soil properties had a higher degree of influence on the channel seepage loss, which was consistent with the conclusion in a study by Li Hongxing [18] et al. On the other hand, the test results show that in the actual water conveyance process, the channel bed soil water content and channel flow rate are dynamically changing with time. The dynamic change in the soil water content and channel flow rate will directly affect the infiltration capacity of the channel bed soil, but the channel bed soil water content and channel seepage rate show the opposite change trend, which is similar to the conclusion of the study by Li Mingyang [25] and others. The flow rate, although the change amplitude is small, still has a large impact on the channel seepage loss, which is similar to the conclusion of the study by Kratz et al. [26]. However, in the course of the experiment, there were cases of low precision in individual data, which may have been influenced by the precision of the real-time soil moisture monitoring instrument. Therefore, in future tests, the influence of various monitoring systems in the field for the test should first be considered, and the measurement interval can be set shorter to obtain more continuous real-time data and improve the accuracy of the data. In addition, the precipitation during the test period will affect the channel flow, soil moisture content, and other factors. A subsequent study should fully consider the interference of precipitation on the test. The precipitation factor can be used as a regression factor for regression analysis through the regression coefficient to quantify its impact on the channel seepage.

5. Conclusions

In this study, a dynamic simulation model of multi-factor channel leakage loss was constructed through a machine learning method, and a dynamic simulation test of leakage loss was carried out in the irrigation area to verify the model accuracy, aiming at accurately calculating the channel leakage loss under the dynamic change in the influencing factors, providing effective support for the irrigation area to accurately control the process of channel water conveyance. The research results show that under the conditions of considering the dynamic changes of some influencing factors in the water transfer process and quantifying the degree of influence of multi-factors, the dynamic simulation and calculation model of multi-factor channel leakage loss constructed by using the machine learning method has a better calculation effect than the traditional empirical formula. The model constructed using the machine learning method has higher computational accuracy than the traditional empirical formula. In addition, the model can simulate the dynamic trend of seepage loss more intuitively, which can provide an effective method for irrigation districts to determine the seepage characteristics of the channel, so as to provide strong support for the realization of the precise control of the channel water transfer process.

Author Contributions: Conceptualization, J.M.; methodology, B.C. and J.Y.; software, J.Y., X.H. and B.C.; analysis and validation, J.Y.; data curation, J.Y.; writing—original draft, J.Y.; review, B.C. and S.Y.; visualization, S.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Henan province university science and technology innovation talent support plan project (No. 15HASTIT046), Henan province science and technology research project (No. 152102110095), and key scientific research projects of colleges and universities in Henan Province (No. 15A570008). Therefore, we thank the Department of Education and the Department of Science and Technology of Henan Province for their strong support.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Derived data supporting the findings of this study are available from the corresponding authors on request.

Conflicts of Interest: The authors declare no conflict of interest.

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