Study on the path of electrical automation technology to achieve low carbon emission and sustainable development in water irrigation system

Abstract: The arrival of the information society, electrical automation of agricultural irrigation work has an important role, the continuous exploration of science and technology and breakthroughs, electrical automation technology has been a step-by-step reform and innovation, and the close integration of the development of agriculture, greatly promoting the national economic development. This paper realizes the automation, precision and intelligent control of agricultural machinery and equipment through electrical automation technology, and designs the water irrigation system software control process to improve the operation process of water irrigation system tasks. The root-mean-square algorithm is used to control the water irrigation process, and the atmospheric temperature, soil humidity, and leaf temperature of the crops are measured in the water irrigation process. Kaya decomposition and spatial autocorrelation model were introduced to measure the agglomeration value of carbon emissions from hydraulic irrigation and the spatial distribution of the agglomeration. Simulation experiments of hydraulic irrigation schemes were conducted to explore the characteristics of carbon emissions during hydraulic irrigation. Based on the delineated boundaries and ranges, it was calculated that the total carbon emission from agricultural irrigation in the test area in 2023 was 34.38×10^4 t, of which hydraulic irrigation accounted for 33.78% of the carbon emission from land management. The lowest emission rate of carbon emissions during the crop irrigation period occurs around 04:00 to 06:00 and is 8.19853 $umols^{-1}m^{-2}$. Based on the experimental data, the sustainable development strategy of electrical automation technology in water irrigation is further proposed.

Keywords: Electrical automation technology; water irrigation system; root mean

square algorithm; Kaya decomposition; spatial autocorrelation modeling

1. Introduction

In the past, most of the agricultural production is based on artificial irrigation, this mode of operation, although it can meet the growth needs of crops, but the cost of manpower, material resources, financial resources and time, etc. is also very obvious, especially in the process of operation, once the relevant information obtained and the actual situation does not match, it will be easy to appear a large number of water resources are wasted phenomenon [1-4]. Therefore, in order to improve the status quo and realize the low-carbon emission and sustainable development of agriculture, it is necessary to actively use electrical automation technology to control the agricultural irrigation system, as far as possible in accordance with the corresponding specifications to accurately calculate the amount of water consumption, and combined with the actual irrigation needs, reasonably adjust the number of irrigation [5-8].

Electrical automation refers to the use of electrical technology to realize the automatic control of certain systems, equipment or processes. Through electrical automation technology, it can realize the intelligence and automation of equipment, improve work efficiency, reduce labor intensity, and at the same time reduce the safety hazards caused by human operation [9-12]. In the whole operation process, the relevant technicians only need to supervise the operation through the monitoring system on the side, and make a detailed record of the specific problems that exist in the daily irrigation operation, in order to use this as a basis to find out the risks and failures that exist in the operation process [13-16]. By proposing safe and reliable solution strategies, so as to improve the efficiency of agricultural irrigation work, reduce the cost of agricultural irrigation, so as to save water resources on the basis of truly highlighting the environmental advantages of automated irrigation systems [17-19].

Literature [20] proposed a system to manage facilities in water scarce areas using minimum soil moisture sensing elements and temperature sensing elements, which realized intelligent irrigation through embedded control technology, increased trip agricultural production and improved soil health. Literature [21] designed and tested a computer-based automatic drip irrigation control and monitoring system that can be fully controlled by the farmer through on-screen commands and is capable of sending periodic alerts and automatic e-mail notifications to the user about the condition of the greenhouse. Literature [22] designed loT automatic irrigation system using embedded technology and IoT, which can be based on humidity, light and other conditions obtained from sensors, thus providing the required water to the plants and realizing an effective method of water conservation. Literature [23] describes an automated system for the irrigation process where the user can provide the required water level to the particular crop and use the system for the precise irrigation process which helps in reducing the water wastage. Literature [24] pointed out the problems of irrigation practices and emphasized the importance of modernizing agricultural practices, which not only increases water productivity and conserves resources, but also maintains soil water potential. Literature [25] proposed a drip irrigation automation system which captures soil images and calculates humidity water through a smartphone, thus transmitting the data to a microcontroller, which achieves good water savings compared to traditional flood and drip irrigation methods.

In this paper, electrical automation technology is applied to the automation, precision, intelligence and remote control of agricultural machinery and equipment. The control software and algorithm of the water irrigation system were designed based on the control software process to improve the water irrigation task. The root-mean-square algorithm was used to set the conditions to meet the irrigation and realize the water irrigation control of the system. Atmospheric temperature, soil humidity and leaf temperature during the operation of the water irrigation system were measured to experimentally test the operation of the electrical automated water irrigation system. Construct Kaya decomposition and spatial autocorrelation model to measure the spatial autocorrelation of carbon emissions in the test area. Combining the experimental treatments and irrigation schemes, the carbon emission characteristics of water irrigation are described and analyzed, and the sustainable development path of water irrigation system under electrical automation technology is clarified.

2. Design of water irrigation system based on power automation technology

2.1 Application of machinery and equipment control

The application of electrical automation technology in the control of agricultural machinery and equipment is a very important technical breakthrough. With the continuous development and popularization of agricultural machinery and equipment, the application of electrical automation technology is also more and more extensive. In the control of agricultural machinery and equipment, electrical automation technology is mainly applied to the following aspects.

2.1.1 Automated controls

Automation control is the most widely used electrical automation technology in the control of agricultural machinery and equipment. Through the automation control technology, the automation control of agricultural machinery and equipment can be realized to improve the production efficiency and quality.

2.1.2 Precision control

Precision control is an important application of electrical automation technology in the control of agricultural machinery and equipment [26]. Through the precision control technology, it can realize the real-time monitoring and adjustment of various parameters of agricultural machinery and equipment to ensure the stability and precision of the production process.

2.1.3 Intelligent control

Intelligent control is an emerging application of electrical automation technology in the control of agricultural machinery and equipment. Through intelligent control technology, intelligent control and management of agricultural machinery and equipment can be realized to improve production efficiency and quality.

2.1.4 Remote control

Remote control is an innovative application of electrical automation technology in the control of agricultural machinery and equipment. Through remote control technology, remote control and monitoring of agricultural machinery and equipment can be realized to improve production efficiency and management effect.

2.2 System architecture and functionality

2.2.1 Control system software and algorithm design

The use of water and electricity dual-control system for irrigation management and control can not fully achieve the purpose of low-carbon emissions, but also need to control irrigation from the technical aspects, so as to jointly realize low-carbon emission irrigation in both management and technology. According to the different crops on the temperature and humidity requirements of different and different ranges, from the technical design of irrigation, select and crop growth closely related to the three factors, respectively, the atmospheric temperature, soil humidity and leaf temperature as a control factor, and will collect data and set the reference value for comparison, so as to realize the low-carbon emission irrigation. For different crops, it is only necessary for the staff to input the reference values of the control factors to realize the usability of the system.

2.2.2 Control system software design

The system software includes the following steps in realizing the irrigation process.

(1) Initialization. Keyboard management, display and hardware each chip initialization, read the initial parameters of the system configuration, the formal invocation of the operating system, so that the system can operate normally.

(2) Acquisition of data. The user's water consumption and power consumption information is collected by the information collection module and passed to the control module.

(3) Processing of data. The collected data are analyzed and calculated until the conclusion is output.

(4) Output of instructions. Output the irrigation instruction and pass it to the execution module.

(5) Irrigation. When the irrigation instruction is received, the card swiper reads the user information of the IC card and displays the user-related data information on the LCD screen, after which the pump is turned on to start irrigation. At the same time, it communicates with electromagnetic flow meter and electricity meter in real time, and calculates the cost according to the set unit price of electricity and water until the end of irrigation. Swipe the card and read the IC card information again to complete the charge.

(6) Information transmission. The water charge, electricity charge and IC card balance during the irrigation process are displayed in real time on the LCD screen, and at the same time, the user-related information is transmitted to the relevant module through GPRS, and finally the irrigation task is completed. The flow of the control software is shown in Figure 1.

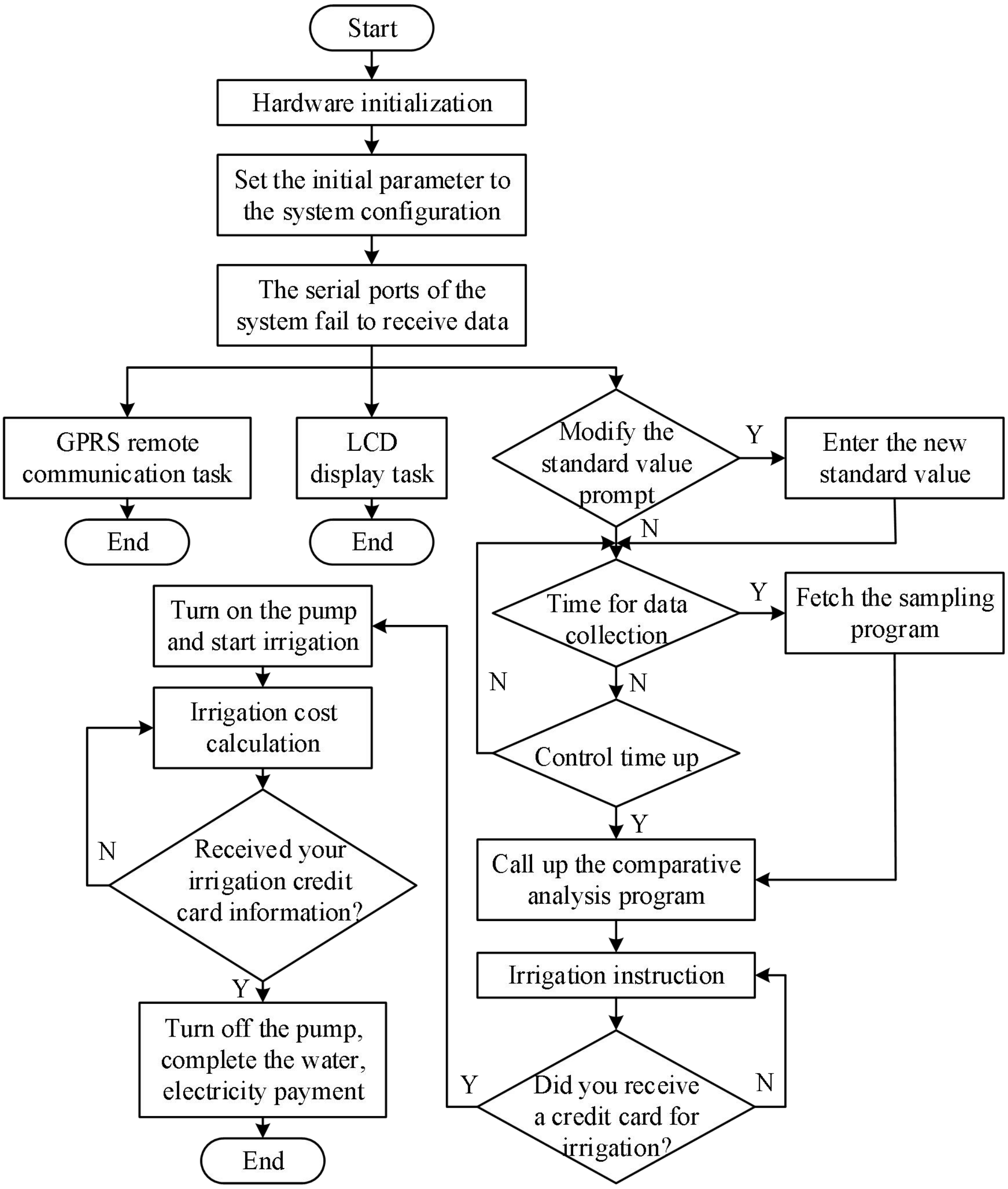


Figure 1 Flow chart of control software

2.2.3 Control system algorithm design

For water irrigation, the design of the control algorithm is the key, if the algorithm is more complex, the requirements for hardware are higher. In order to facilitate the control, while taking into account the requirements of crops on the factors in the environment, the root mean square algorithm is used to control the irrigation process [27].

Firstly, the irrigation control factors were set to be air temperature T_1, humidity H_2 and foliar temperature T_l, and the variable range of these three factors was set to be $T_1 = (T_{1\min}, T_{l\max}), H_2 = (H_{2\min}, H_{2\max}), T_l = (T_{l\min} T_{l\max})$ respectively.

At this time, the standard deviations $\varepsilon_1, \varepsilon_2$ and ε_3 corresponding to the 3 factors were:

$$\varepsilon_1 = \frac{T_{1\max} - T_{1\min}}{2} \tag{1}$$

$$\varepsilon_2 = \frac{H_{2\max} - H_{2\min}}{2} \tag{2}$$

$$\varepsilon_3 = \frac{T_{l\max} - T_{l\min}}{2} \tag{3}$$

Means $T_1^{'}, H_2^{'}$ and $T_{l3}^{'}$, respectively:

$$T_1^{'} = \frac{T_{1\max} + T_{1\min}}{2} \tag{4}$$

$$H_2^{'} = \frac{H_{2\max} + H_{2\min}}{2} \tag{5}$$

$$T_{l3}^{'} = \frac{T_{1\max} + T_{1\min}}{2} \tag{6}$$

During the sampling period, the number of samples for the three factors was n_1, n_2 and n_3, and the sampling results were T_{1i}, H_{2i} and T_{li}, respectively, from which the root mean squares $\varepsilon_1, \varepsilon_2$ and ε_3 of the three influences can be determined:

$$\varepsilon_1^{'} = \sqrt{\frac{\sum_{i=1}^{n_1} (T_i - T_i^{'})^2}{n_1}} \tag{7}$$

$$\varepsilon_2^{'} = \frac{\sqrt{\sum_{i=1}^{n_2} (H_{2i} - H_2^{'})^2}}{n_2} \tag{8}$$

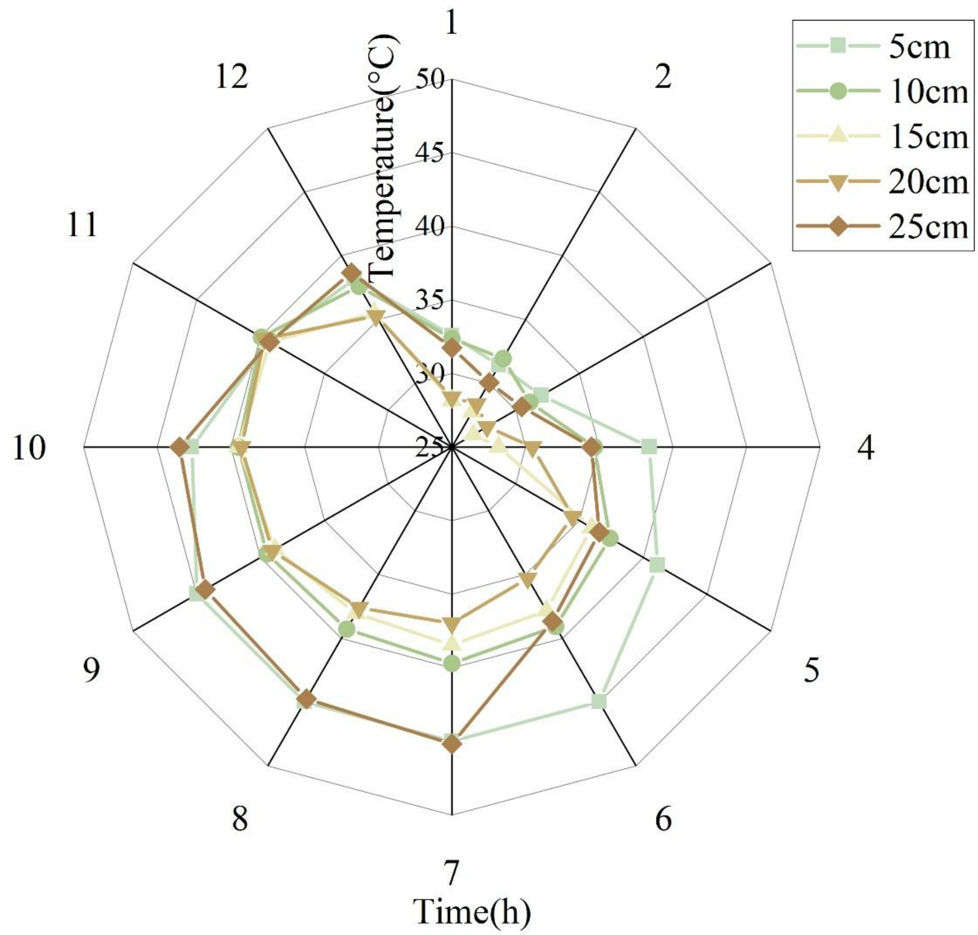
$$\varepsilon_3^{'} = \frac{\sqrt{\sum_{i=1}^{n_3}(T_{li} - T_{l3}^{'})^2}}{n_3} \tag{9}$$

When two of the following conditions $\varepsilon_1^{'} > \varepsilon_1, \varepsilon_2^{'} > \varepsilon_2, \varepsilon_3^{'} > \varepsilon_3$ are met, the system turns on irrigation. During the irrigation process, when any two of the following conditions $\varepsilon_1^{'} \le \varepsilon_1, \varepsilon_2^{'} \le \varepsilon_2, \varepsilon_3^{'} \le \varepsilon_3$ are met, the system stops irrigation, which can realize the water irrigation control of the system [28].

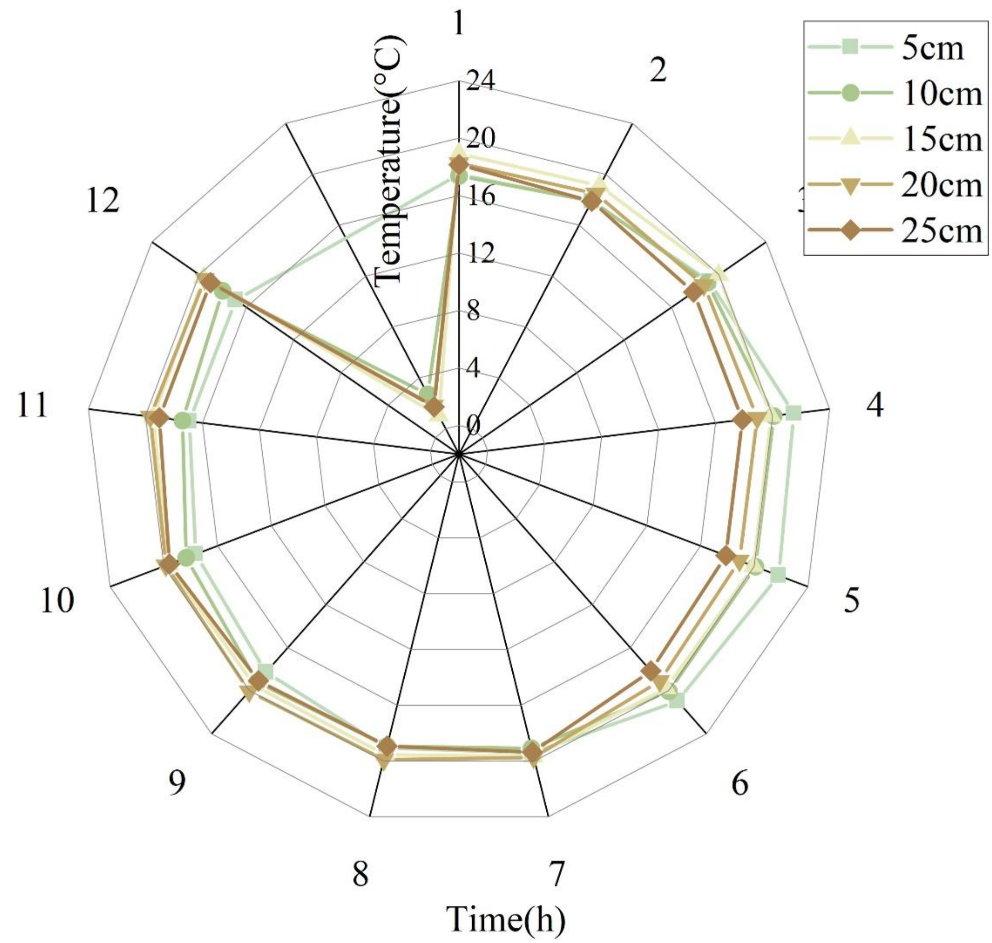
2.3 Electrical automation water irrigation system operation experiment

2.3.1 Atmospheric temperature

Figure 2 shows the daily variation process of soil temperature at different distances, Figure (a) is at 20cm from the surface and Figure (b) is at 40cm from the surface. The daily variation of soil temperature at different distances from the pit wall is shown in Fig. 2 at 20cm and 40cm from the ground surface. It can be seen that the maximum variation of soil temperature at 5cm from the pit wall at the 20cm level from the surface of the water storage pit is 13.58℃, and the variation of soil temperature at 10-25cm from the pit wall is within 8.84-15.1℃. The soil temperature at 5cm from the pit wall at the level of 40cm from the surface of the water storage pit varied by 4.91℃, and the soil temperature at 10~25cm from the pit wall varied by 1.02~2.71℃.



(a)20cm from the surface



(b)40cm above the surface

Figure 2 Diurnal variation of soil temperature

2.3.2 Soil moisture

Figure 3 shows the soil water content change of different treatment irrigation, because the irrigation quota is the same in the seedling emergence period, so the trend of soil water content change after irrigation is basically the same for all treatments, and the controlled test was conducted from May 20, and the average value of soil water content treated with the water irrigation system designed using the electrical automation technology was 13.57%, and that treated with the traditional irrigation technology was 13.46%, and that of the electrical automated water irrigation system increased the soil water content by 0.11% compared to the traditional water irrigation treatment, the minimum water content of the two treatments was divided into 12.196% and 11.295%, and the soil water content of the electrical automated water irrigation system treatment increased by 0.901%.

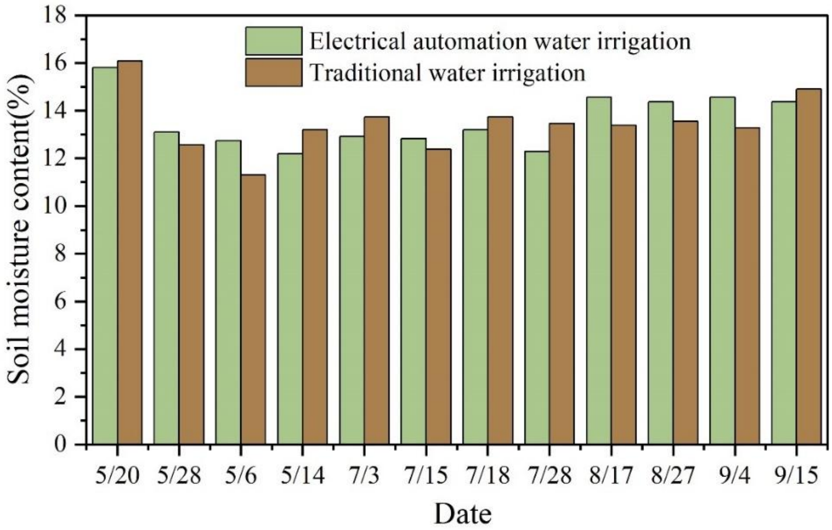


Figure 3 Different soil moisture content changes in irrigation

2.3.3 Leaf Temperature

Figure 4 shows the blade temperature difference, which fluctuates around -0.4~-0.25°C in the time periods of 2024/4/26 and 2024/8/25, and reaches a maximum value of 3°C around 2024/3/20 with the enhancement of solar radiation and the increase of atmospheric temperature.

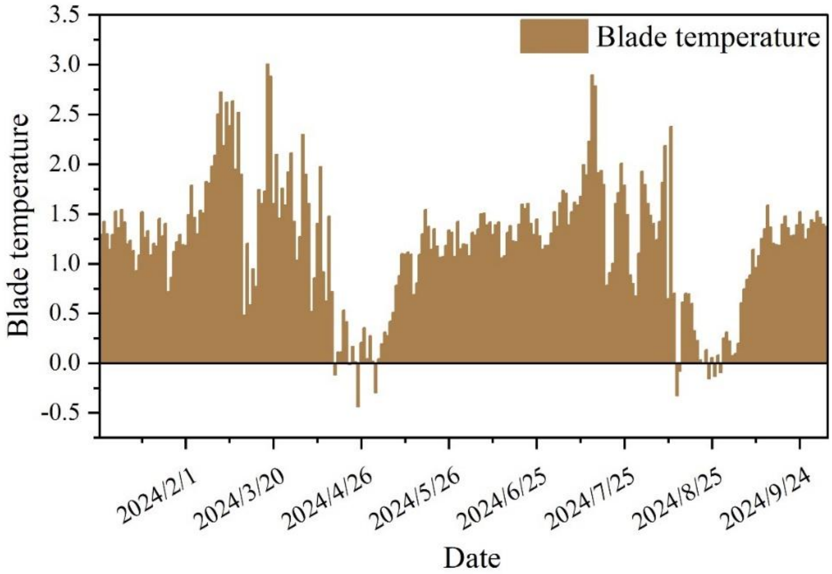


Figure 4 Blade temperature difference

3. Study of carbon emissions in water irrigation systems

3.1 Study of spatial patterns of carbon emissions

3.1.1 Measuring Carbon Emissions from Water Irrigation

Given the limitations of data acquisition, agriculture in this study refers to agriculture in a narrow sense, i.e., cultivation. Since the CO_2 emission source generated by water irrigation has a strong potential to reduce emissions, this study mainly measures the agricultural carbon emissions generated by water irrigation. By combing the existing research results, this study mainly adopts the IPCC carbon emission coefficient method to measure the carbon emissions from agricultural water irrigation in the Yellow River Basin. Combined with the current situation of agricultural development in the study area, the measurement method of agricultural water irrigation carbon emissions is shown in Equation (10). It should be noted that the temporal change characteristics of agricultural irrigation carbon emissions in the Yellow River Basin and the spatial change characteristics at the provincial scale are carried out for nine provinces and districts in the study area from 2023 to 2024. Considering the availability of data, the analysis of the spatial change characteristics of agricultural irrigation carbon emissions and influencing factors at the municipal scale is carried out based on the relevant data in 2023 only:

$$E_i = \sum_{j=1}^{m} E_{ij} = \sum_{j=1}^{m} T_{ij} \times \delta_j \quad (10)$$

Where: E_i is the carbon emission (10^4 t) from irrigated agricultural water in the i nd study unit, E_{ij} is the carbon emission (10^4 t) from the j th carbon source in the i th study unit, T_{ij} is the usage (10^4 t) from the j th carbon source in the i th study unit, and δ_j is the emission coefficient of the j th carbon source.

(1) Kaya decomposition model

The carbon emissions caused by water irrigation activities are attributed to carbon emission intensity, energy use intensity, economic development level and population size. According to the Kaya analysis framework, and combined with the characteristics of carbon emissions from irrigation, the carbon emissions from agricultural irrigation are decomposed as follows:

$$C_i = \frac{C_i}{AGRI_i} \times \frac{AGRI_i}{AGR_i} \times \frac{AGR_i}{P_i} \times P_i \tag{11}$$

$$EI_i = \frac{c_i}{AGRI_i} \tag{12}$$

$$AI_i = \frac{r_i}{AGRI_i} \tag{13}$$

$$EL_i = \frac{AGR_i}{P_i} \tag{14}$$

Where: $C_i, AGRI_i, AGR_i, P_i$ respectively for the i nd research unit of agricultural carbon emissions (10^4 t), planting output (10^4 yuan), agriculture, forestry, animal husbandry and fishery output (10^4 yuan), agricultural labor force size (10^4 people), EI_i, AI_i, EL_i respectively the i th research unit of agricultural production efficiency.

(2) Spatial autocorrelation model

Spatial autocorrelation mainly studies whether the observation value of a position in space is related to the observation value of its neighboring positions, and can reveal the regional structure of spatial variables in the form of global spatial autocorrelation and local spatial autocorrelation. Global spatial autocorrelation is used to measure the degree to which attribute values of spatial features are clustered or dispersed throughout an area. Local spatial autocorrelation measures various agglomeration values as well as the spatial distribution of agglomeration.

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(X_i - \bar{X})(X_j - \bar{X})}{(\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij})\sum_{i=1}^{n}(x_i - \bar{X})^2} \tag{15}$$

$$I_i = \frac{n(X_i - \overline{X})\sum_{j=1}^{n} W_{ij}(X_j - \overline{X})}{\sum_{i=1}^{n}(X_i - \overline{X})^2} \tag{16}$$

where I is the Moran index, n is the number of spatial units, X_i and X_j denote the attribute values of spatial units i and j, $\overline{X}$ is the average value of carbon emissions, and W_{ij} is a matrix of spatial weighting coefficients, which denotes the adjacency of each spatial unit [29].

3.1.2 Spatial autocorrelation

Figure 5 shows the Sankey diagram of carbon emission from agricultural irrigation in the Yellow River Basin. Based on the delineated boundaries and ranges, it is calculated that the total carbon emission from agricultural irrigation in the Yellow River Basin in 2023 will be $34.38\times10^4\,t$. The carbon emission of land management is more than that of agricultural materials, and the carbon emission of water irrigation is 33.78% of the carbon emission of land management.

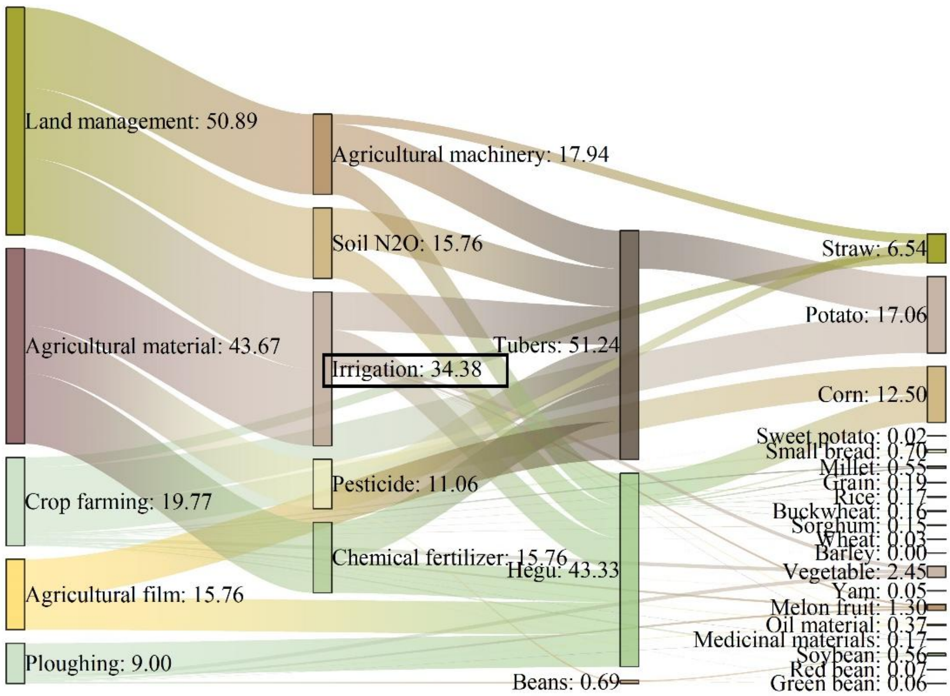


Figure 5 Carbon emissions from agricultural irrigation in the Yellow River Basin

Figure 6 shows the Moran′s I scatter plot of carbon emissions from irrigated agricultural water in 2023, and Moran′s I based on the distance spatial weight matrix was used to test the spatial autocorrelation of carbon emissions from the test area in 2023. From the test results, the Moran′s I index of the spatial matrix is greater than 0 to 0.5463, and the standardized test value (z) is greater than 2.55, indicating that there is spatial agglomeration in the spatial distribution of carbon emissions, and that changes in carbon emissions from irrigated agricultural water conservancy are affected by spatially related factors.

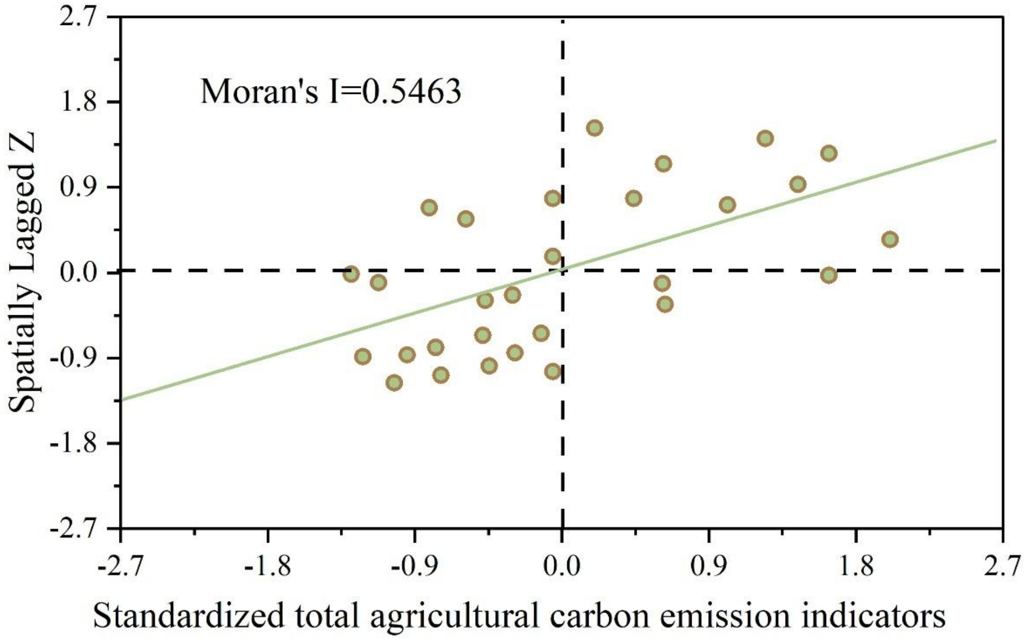


Figure 6 2023 the agricultural water irrigation carbon emissions Moran′s I

3.2 Carbon Emission Characteristics of Water Irrigation

3.2.1 Experimental design

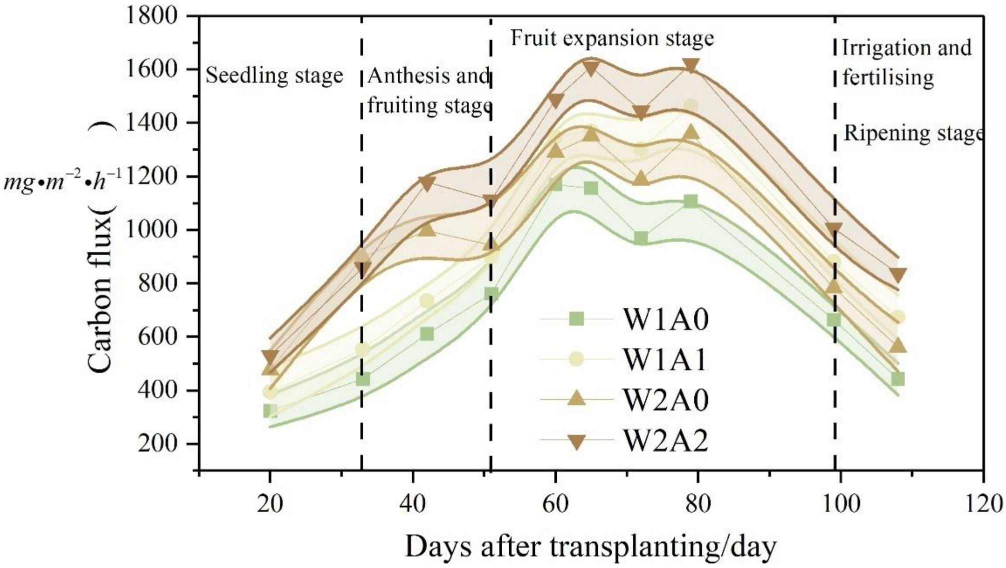
Table 1 shows the experimental treatments and irrigation schemes, based on the local conventional irrigation experience (irrigation water amount of 4300 m^3/hm^2), the experiment set W1 (3800 m^3/hm^2), W2 (4300 m^3/hm^2) 2 irrigation levels. A0 (6mg / L) and A1 (17mg / L) 2 water body dissolved oxygen concentration. H0 (0, on behalf of humic acid accounted for the humic acid in the sum of the mass of the potassium dihydrogen phosphate, urea and humic acid three proportions, hereinafter the same), H1 (0.23%) and H2 (0.52%) 3 humic acid applied, of which, potassium dihydrogen phosphate KH_2PO_4 contains 32.8% and 51.3% P_2O_5 , and urea K_2O contains 46.3% N. A total of 12 treatments were used in a complete combination experimental design, with CH_4N_2O replications for each treatment, and 1 replication is 1 experimental plot, i.e. 36 plots. The area of each plot was 14.2 m^2 (10 m long and 1.42 m wide).

Table 1 Experimental treatment and irrigation schemes

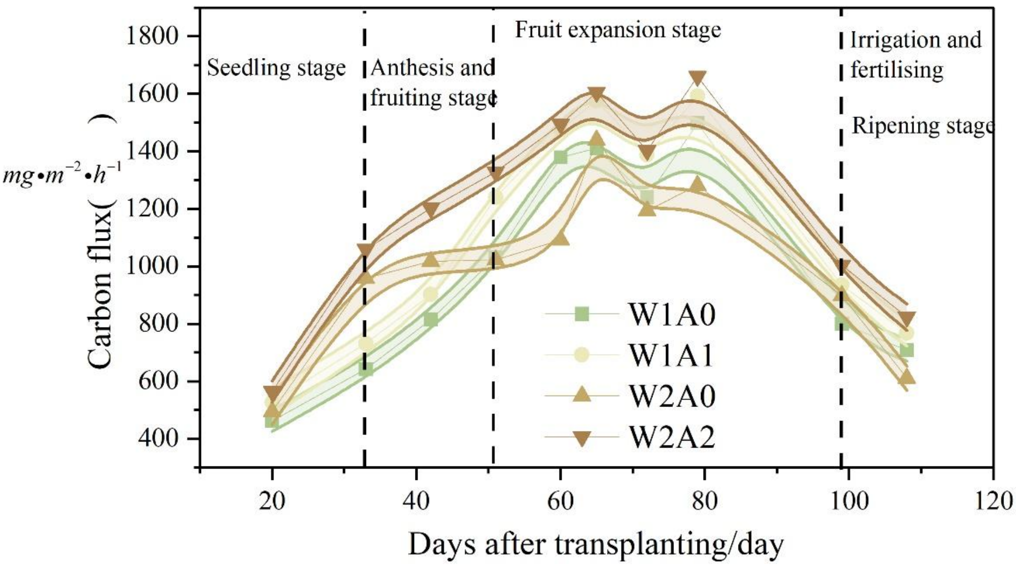
Serial number	Treatment	Concentration of dissolved oxygen in water/ $(mg{\bullet}L^{-1})$	Humic acid addition/%	Irrigation level/ $(m^3{\bullet}hm^{-2})$
1	W2A0H0	5(without gas)	0	4300
2	W2A0H1		0.23	
3	W2A0H2		0.52	
4	W2A1H0	18(Micro and nano)	0	
5	W2A1H1		0.23	
6	W2A1H2		0.52	
7	W1A0H0	5(without gas)	0	3800
8	W1A0H1		0.23	
9	W1A0H2		0.52	
10	W1A1H0	18(Micro and nano)	0	
11	W1A1H1		0.23	
12	W1A1H2		0.52	

The soil CO_2 emission rate of each hydroirrigation treatment was similar in the whole reproductive period of agricultural hydroirrigation, basically in the form of a double-peak curve, and both peaks appeared in the fruit expansion period. Figure 7 shows the pattern of change of carbon emission fluxes under the treatment of hydraulic irrigation system, with H0 in Figure (a), H1 in Figure (b), and H2 in Figure (c), and the effect of hydraulic irrigation had a highly significant effect on the CO_2 emission fluxes. Among them, the emission flux of soil CO_2 in the W2H2A2 treatment was always the largest, with two peaks of 1725.67873 $mg{\bullet}m^{-2}{\bullet}h^{-1}$ and

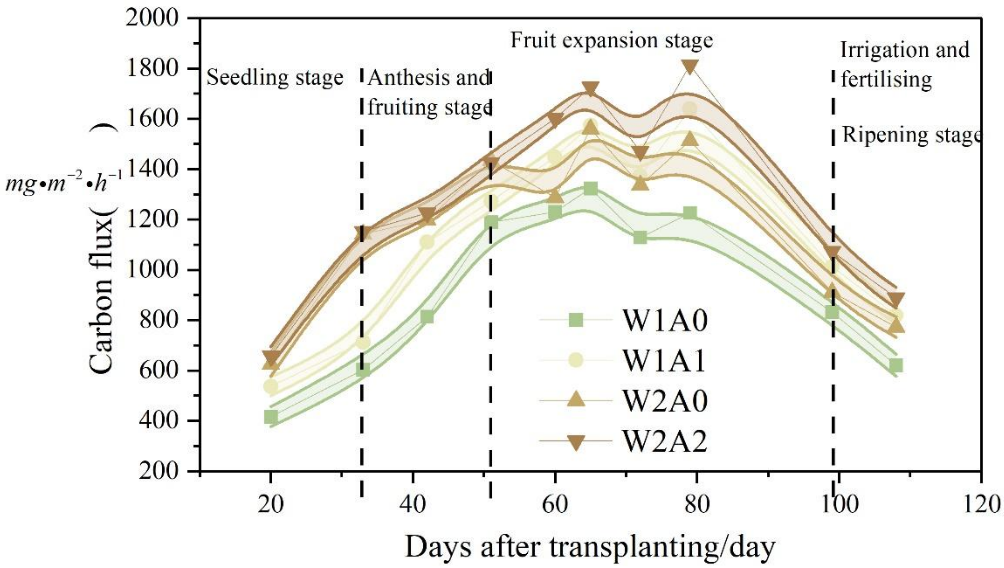
1813.34842 $mg{\bullet}m^{-2}{\bullet}h^{-1}$, which were basically significantly different from the other treatments except W2H0A1 and W2H1A1, and the emission flux of W1H0A0 CO_2 was always the smallest, with an average emission of 764.762 $mg{\bullet}m^{-2}{\bullet}h^{-1}$, which was basically significantly different from the other treatments.



(a)H0



(b)H1



(c)H2

Figure 7 The law of carbon flux variation of carbon discharge under irrigation system

3.2.2 Carbon Sequestration and Carbon Emissions in Different Irrigation Treatments

Table 2 shows the carbon sequestration and carbon emission of different hydraulic irrigation treatments, increasing irrigation level, increasing humic acid application and aerated drip irrigation all had highly significant positive effects on CO_2 cumulative emission flux, carbon initial productivity CIP (45% of biomass at harvest) and net carbon sequestration NCS. The CO_2 cumulative emission fluxes, CIP and NCS of agricultural irrigation increased significantly with increasing irrigation levels, and the cumulative emission fluxes, CIP and NCS of the irrigation treatments of W2H2A1 were 29.718±3.036, 138.965±14.536 and 134.545±14.595, respectively, and compared with the W1 treatments, the indicators under W2 treatments increased significantly by 17.48%, 24%, 24% and 24%, respectively, with the W1 treatments. Compared with W1 treatment, the indicators under W2 treatment were significantly increased by 17.48%, 24.18% and 25.71% respectively. H2 treatment was significantly increased by 4.77%, 11.15% and 13.58% compared with H1 treatment, and by 18.36%, 25.09% and 27.81% compared with H0 treatment, and the cumulative emission fluxes from hydraulic irrigation to agricultural irrigation CO_2 had a highly significant effect.

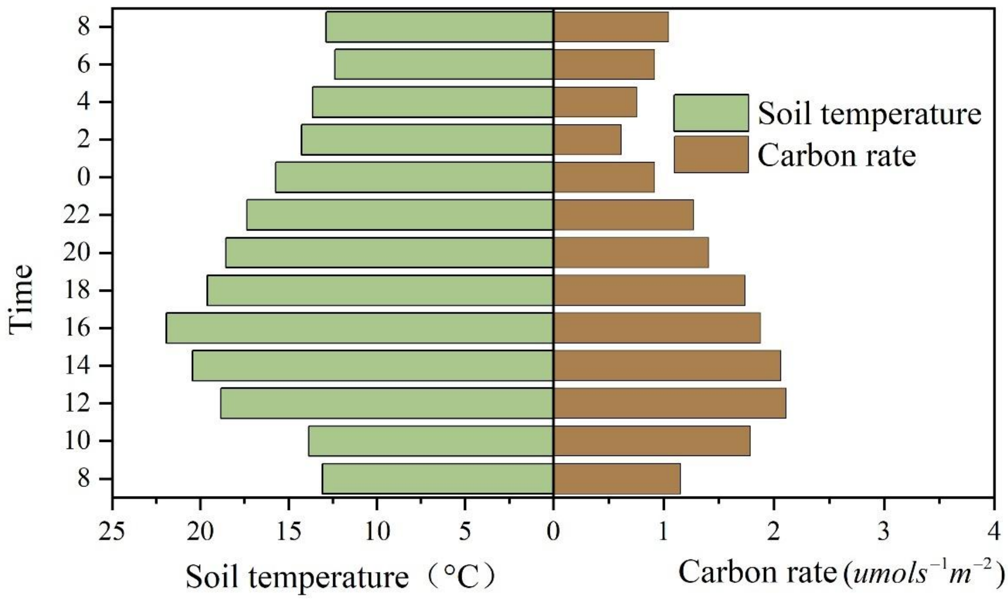
Table 2 Carbon and carbon emissions of different water irrigation

Treatments	Cumulative CO_2 emissions/ $(t \cdot hm^{-2})$	Carbon Initial Productivity/ $(t \cdot hm^{-2})$	Net carbon sequestration/ $(t \cdot hm^{-2})$
W1H0A0	17.165±1.425	81.236±7.984	75.564±7.765
W1H0A1	21.526±2.436	91.623±9.036	85.436±8.132
W1H1A0	22.536±2.548	88.018±8.425	83.465±8.465
W1H1A1	25.236±2.215	95.148±9.269	89.245±8.261
W1H2A0	21.136±2.248	108.485±10.648	105.654±10.626
W1H2A1	25.945±2.369	114.669±11.496	108.654±10.463
W2H0A0	22.615±2.348	98.265±9.265	93.485±9.728
W2H0A1	26.348±2.399	113.425±13.645	108.965±10.536
W2H1A0	23.458±2.315	114.695±11.695	107.599±10.436
W2H1A1	27.798±2.436	134.945±13.612	128.648±13.618
W2H2A0	26.948±2.715	118.926±11.523	115.654±11.569
W2H2A1	**29.718±3.036**	**138.965±14.536**	**134.545±14.595**

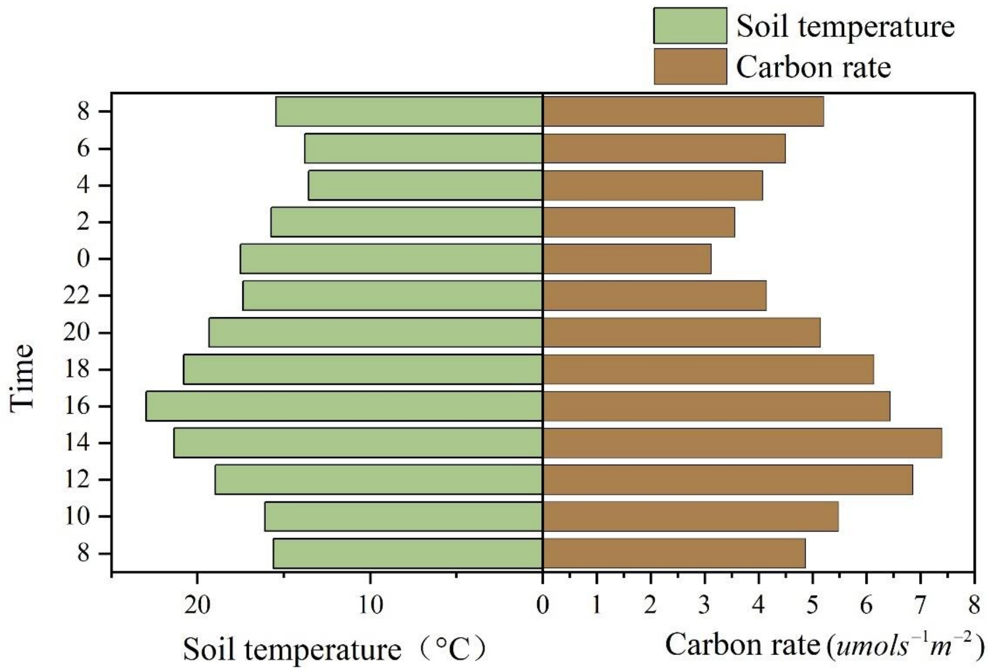
3.3 Daily variation in carbon emission rates

The test treatment plots were selected to measure the CO_2 daily variation of emission rate as shown in Fig. 8 at three periods: tillering, tasseling and irrigation periods of the crops, Fig. (a) for tillering, Fig. (b) for tasseling and Fig. (c) for irrigation periods. CO_2 The daily variation of respiration rate showed a single peak variation and was basically consistent with the diurnal variation of soil temperature. CO_2 The lowest value of emission rate appeared around 04:00~06:00, and the carbon emission rate was 12.36991 $umols^{-1}m^{-2}$, 13.56618 $umols^{-1}m^{-2}$, and 18.19853 $umols^{-1}m^{-2}$ in the three periods, respectively. The maximum value occurred around 16:00. The order of soil CO_2 emission rate was spike > irrigation > tillering.

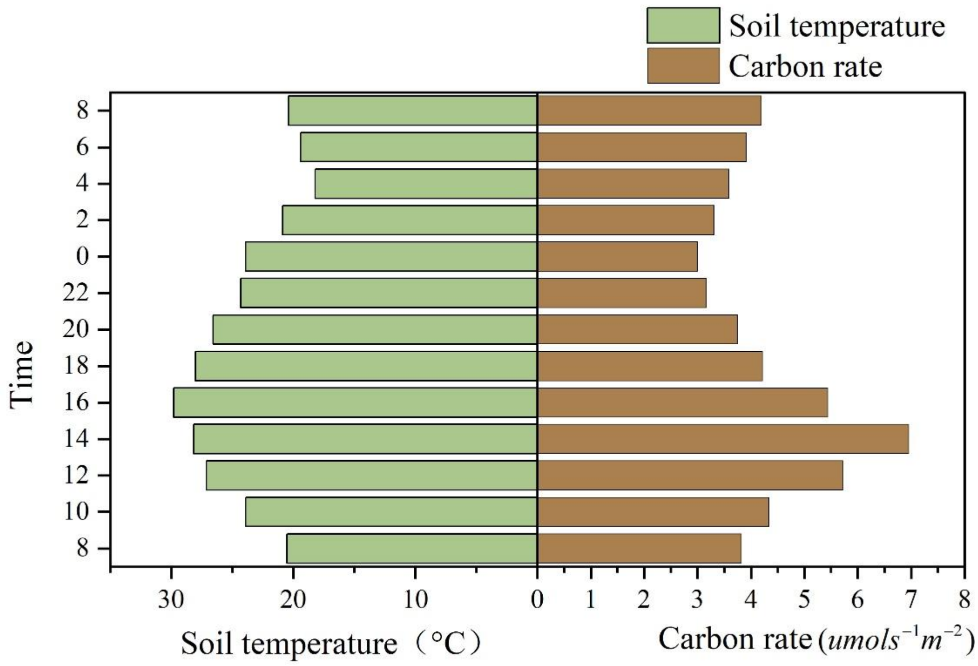
It was found that the daily average of soil CO_2 emission rate in the three periods was close to that measured at about 10:00 a.m. Therefore, when calculating the carbon emission in each fertility stage, the measured value at 10:00 a.m. in each fertility period can be used as the basis.



(a)Tillering stage



(b)Heading period



(c)Filling period

Figure 8 CO_2 discharge rate day change

4. Sustainable development pathways for water irrigation systems

4.1 Strengthening infrastructure and promoting precision agriculture technologies

4.1.1 Promotion of drip and sprinkler irrigation systems

The promotion of drip and sprinkler irrigation systems is an important technological measure to improve the efficiency of low-carbon emissions from agricultural land. Drip irrigation systems can deliver water directly to plant roots, thereby reducing evaporation and wastage, and are particularly suitable for use in arid areas where water is scarce. Sprinkler irrigation systems can distribute water evenly over a wide area and are suitable for a wide range of crops and terrains. For this reason, relevant ministries and agencies should encourage farmers to adopt these efficient irrigation technologies in order to significantly improve water use efficiency and crop yields.

4.1.2 Upgrading of water distribution infrastructure

Upgrading water distribution infrastructure is a key technical measure for improving irrigation efficiency. Improving irrigation channels and pipe networks to reduce water loss and evaporation during transport is an effective way to enhance the overall efficiency of irrigation systems. At the same time, the application of modern pump and valve technology allows for more precise control of water flow and ensures that water resources are utilized efficiently and rationally.

4.1.3 Promotion of precision agriculture technologies

The promotion of precision agriculture technologies is an important way to improve water use efficiency and crop yields. Precision agriculture technologies, such as soil moisture monitoring, climate data analysis and crop growth modeling, can help farmers adjust irrigation schedules to actual conditions.

4.1.4 Application of remote sensing and monitoring techniques

The use of remote sensing and monitoring technologies is a modern approach to achieving efficient, low-carbon emission irrigation. These technologies can provide real-time data on soil, climate and crop conditions to help farmers make more accurate irrigation decisions. The use of technologies such as satellite remote sensing, drone monitoring and ground-based sensors can better monitor the on-farm environment and guide the development and adjustment of irrigation schedules, thereby improving water use efficiency and agricultural productivity.

4.2 Real-time irrigation detection and enhanced soil moisture monitoring

4.2.1 Adoption of efficient water utilization methods

The adoption of efficient water utilization methods is critical to achieving the goal of efficient and low-carbon emission irrigation. Methods such as drip, microsprinkler and soakaway irrigation, for example, can deliver water accurately to crop roots or water-demanding areas, thereby greatly reducing water evaporation and loss. These methods enhance water-use efficiency and help conserve water resources while improving crop growth.

4.2.2 Monitoring and adjusting real-time irrigation data

Irrigation monitoring and adjustment based on real-time data is an effective way to improve irrigation efficiency. The use of weather stations, soil moisture sensors and other monitoring equipment to collect data can provide a precise understanding of the water needs of crops, thus enabling precise irrigation. This approach helps to avoid over-irrigation or under-watering and ensures the rational use of water resources.

4.2.3 Application of soil moisture sensors

In modern agriculture, the application of soil moisture sensors can effectively improve irrigation efficiency. These sensors can accurately monitor soil moisture, providing critical information for irrigation decisions. By analyzing this data, farmers can more accurately determine the optimal timing and amount of irrigation, reducing water waste and improving growing conditions for their crops.

5. Conclusion

This paper explores the direction of mechanical equipment control and designs an electric automated water irrigation system from both control system software and algorithms. The use of the electrical automation water irrigation system was evaluated through system operation experiments, in which the atmospheric temperature during the operation of the water irrigation system was within the range of 1.02 to 2.71°C in terms of the soil temperature at a distance of 10 to 25 cm from the pit wall. Soil water content was elevated by 0.11% compared to the traditional water irrigation method, and the leaf temperature difference fluctuated around -0.4 to -0.25°C.

The spatial autocorrelation model was constructed to study the spatial pattern of carbon emission from irrigation, and the total carbon emission from agricultural irrigation in the Yellow River Basin in 2023 was $34.38 \times 10^4 \mathrm{t}$. The carbon emission from land management was more than that from agricultural materials, and the carbon emission from water irrigation was 33.78% of the carbon emission from land management. The Moran′s I index of the spatial matrix is greater than 0 for 0.5463, while the standardized test value (z) is greater than 2.55, indicating that there is spatial agglomeration in the spatial distribution of carbon emissions, and changes in carbon emissions from irrigated agriculture and water conservancy will be affected by spatially related factors.

The CO_2 cumulative emission fluxes, CIP and NCS of different agricultural water irrigation increased significantly with the increase of irrigation level, and the cumulative emission fluxes, CIP and NCS of the irrigation treatments of W2H2A1 were 29.718±3.036, 138.965±14.536, and 134.545±14.595, respectively.

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