Applying Multivariate Auto-Regression Model to Forecast the Water Requirement of Well Irrigation Rice in Sanjiang Plain

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Abstract: Through using the weather data of Fujin City (1985~1999), this research built up a multivariate auto-regression model. According to growth period of rice, the author divided the whole period into six stages. Thus, the ARV (6) model can forecast the water requirement of each growth stage. The model has good effects on fitting and forecasting, and it can be applied in many fields. For example, water saving irrigation, irrigation water management and exploiter the groundwater resource in reason. [Nature and Science, 2004,2(2):8-14]

Key words: multivariate auto-regression model, Sanjiang Plain, well irrigation rice, water requirement, forecast

1 Introduction

Sanjiang Plain is the most important grain production base in China. The area under cultivation of well irrigation for rice has been expanding year after year in last decades. There are 0.7 million hm^2 of paddy land by the end of 1998. Nearly 80 percent are well irrigated. The homeostasis of groundwater resources has been seriously damaged because of excessive opening. More and more pumps can't work and the appearance of funnel has occurred. In Jian Sanjiang department, there were 600 "hanging pumps" in springtime in 1996. Most of the pumps lay off. So, the lacking of groundwater resources has become the restricted factor for its development. Water saving irrigation becomes the most important task at present. Researching on the water requirement rule of well irrigation rice and building up the forecast model have important significance on saving water, using groundwater reasonable, advancing the steady development of agriculture and groundwater resource (Fu, 2000).

2 Brief Introduction of Multivariable Auto-regression Model

There are many models to calculate the crop water requirement. The most representational model has been put forward by Penman, an English scientist in 1942. According to the principle of energy balance, through using Bowen ratio (Bowen, 1926) and the concept of drying power, Penman obtained the model to calculate the latent evaporation (ET_0) by meteorological data, and then to convert to practical water requirement according to crop coefficient (K_c). Many scholars have done a lot of work in this aspect, and many models have been built. For example, by means of selecting one or several factors among air temperature (T), sunlight hours (h), saturation deficiency (d), wind velocity (u) etc, the regression equation can be established respectively, including linear regression equation, exponent equation, logarithm equation, and polynomial equation etc. By means of analyzing the long time observation data and meteorological data, Gray system theory is another kind of method to calculate rice water requirement. It sets up gray forecast model $GM(1,1)$ or $GM(2,1)$ of water requirement sequence and revises residual error by random model. The random model like AR (p) can also be built up as another choice. However, all those models to calculate rice water requirement should be taken according to the data of the corresponding period. Lots of theories and practices indicate that rice water requirement is relative to meteorological factors. However, the meteorological factors in the next period are not easy to get and it is very difficulty to forecast. It can only calculate the water requirement at the same period and can't provide gist for water management in the next year. With analyzing the data, the rice water requirement has the dependent characteristic. There is much influence among each two or more phases. Thereby, the author applies multivariate auto-regression model to build up model (ARV(n)). This kind of model can forecast the water requirement in the next one or several phases according to the relativity among the meteorological factors (Fu, 2000).

2.1 Mathematical expression of ARV(n) model (Du, 1991; Ding, 1988; Yang, 1996)

Supposing the water requirement series as $x_t^{(i)}$ $i = 1,2,3,\cdots,t = 1,2,3,\cdots N$ will be taken into account, (t —time series number). According to the quality of ARV(n), the variable i is not only related to the water requirement in the former one or several stages ($x_{t-1}^{(i)}$), but also related to other meteorological factors of the same stage ($x_t^{(j)}$) and the former one or several stages ($x_{t-1}^{(j)}$). Furthermore, it will be influenced by random factors. The mathematical expression is as the following:

$$\begin{cases} x_t^{(1)} = a_{11}^{(1)}x_{t-1}^{(1)} + \cdots + a_{1p}^{(1)}x_{t-p}^{(1)} + a_{11}^{(2)}x_{t-1}^{(2)} + \cdots + a_{1p}^{(2)}x_{t-p}^{(2)} + a_{11}^{(n)}x_{t-1}^{(n)} + \cdots + a_{1p}^{(n)}x_{t-p}^{(n)} + \mathrm{b}_{11}^{(1)}\varepsilon_t^{(1)} + \mathrm{b}_{12}^{(2)}\varepsilon_t^{(2)} + \cdots + \mathrm{b}_{1n}^{(n)}\varepsilon_t^{(n)} \\ \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \\ x_t^{(n)} = a_{n1}^{(1)}x_{t-1}^{(1)} + \cdots + a_{np}^{(1)}x_{t-p}^{(1)} + a_{n1}^{(2)}x_{t-1}^{(2)} + \cdots + a_{np}^{(2)}x_{t-p}^{(2)} + a_{n1}^{(n)}x_{t-1}^{(n)} + \cdots + a_{np}^{(n)}x_{t-p}^{(n)} + \mathrm{b}_{n1}^{(1)}\varepsilon_t^{(1)} + \mathrm{b}_{n2}^{(2)}\varepsilon_t^{(2)} + \cdots + \mathrm{b}_{nn}^{(n)}\varepsilon_t^{(n)} \end{cases} \quad (1)$$

In formula (1): $a_{np}^{(n)}$ ——the auto-regression coefficient of step p of the n variable. $b_{nn}^{(n)}$ ——the independent random variable of the n series.

Let: $A(1) = \begin{bmatrix} a_{11}^{(1)} & \mathrm{a}_{11}^{(2)} & \cdots \mathrm{a}_{11}^{(n)} \\ \cdots & \cdots & \cdots \\ a_{n1}^{(1)} & \mathrm{a}_{n1}^{(2)} & \cdots \mathrm{a}_{n1}^{(n)} \end{bmatrix}$ $A(2) = \begin{bmatrix} a_{12}^{(1)} & \mathrm{a}_{12}^{(2)} & \cdots \mathrm{a}_{12}^{(n)} \\ \cdots & \cdots & \cdots \\ a_{n2}^{(1)} & \mathrm{a}_{n2}^{(2)} & \cdots \mathrm{a}_{n2}^{(n)} \end{bmatrix}$ $A(p) = \begin{bmatrix} a_{1p}^{(1)} & \mathrm{a}_{1p}^{(2)} & \cdots \mathrm{a}_{1p}^{(n)} \\ \cdots & \cdots & \cdots \\ a_{np}^{(1)} & \mathrm{a}_{np}^{(2)} & \cdots \mathrm{a}_{np}^{(n)} \end{bmatrix}$

$B = \begin{bmatrix} b_{11}^{(1)} & \mathrm{b}_{12}^{(2)} & \cdots & \mathrm{b}_{1n}^{(n)} \\ \cdots & \cdots & & \cdots \\ b_{n1}^{(1)} & \mathrm{b}_{n2}^{(2)} & \cdots & \mathrm{b}_{nn}^{(n)} \end{bmatrix}$ $X_t = \begin{bmatrix} x_t^{(1)} \\ \cdots \\ x_t^{(n)} \end{bmatrix}$ $E_t = \begin{bmatrix} \varepsilon_t^{(1)} \\ \cdots \\ \varepsilon_t^{(n)} \end{bmatrix}$

Then, the above equation can be expressed as the following:

$$X_t = A(1)X_{t-1} + A(2)X_{t-2} + \cdots + A(p)X_{t-p} + BE_t \quad (2)$$

Matrix $A(p)$ expresses the correlation and auto-correlation of every variable series when the lag time is p. Matrix B expresses the correlation when the lag time is zero.

2.2 Steady the series

If the time series has increasing, descending, period and other varied trend, they are all belong to non-steady series. The ARV(n) model converges to steady series, so it must convert to steady series. There are many methods to steady the time series, for trend item, can directly to fit the relevant function using computer and no need to give the function form of trend item, to give a common polynomial first and then, by means of regressing step by step to define the mathematical expression based on computer and can deal with difference also. For period item, to get the steady time series is based on harmonic analysis (Ding, 1998; Wang, 1999; Wang, 2000).

For multivariate time series, to deal the data series is based on the above method also.

2.3 Define the step of ARV(n) (Du, 1991; Wang, 2000)

The steps of model can be defined according to the least FPE rule. The calculated formula is as the following:

$$FPE_p(X_t) = det\hat{D}_p = (1+\frac{kp}{N})^k(1-\frac{kp}{N})^{-k} \, det(\hat{\gamma}_0 - \sum_{i=1}^{p}\hat{A}_{pi}\hat{\gamma}_j^{\tau}) \quad (3)$$

If the value of $FPE_p(X_t)$ is rising at the beginning of $p=1$, the step of the model is 1. If the value of $FPE_p(X_t)$ descends when p is increases, perhaps the sample series can't be described by AR model. If the value of $FPE_p(X_t)$ descends quite soon at a certain p, it will descend slowly. To take this p is as the step of model.

If the value of $FPE_p(X_t)$ sway acutely along with the p increasing, and has no least value, the sample series should increase the length of series.

2.4 Calculate the parameters of ARV (n) model

The correlation coefficient is calculated as the following (Ding, 1988)

$$r_k^{ij} = \frac{\sum_{i=k+1}^{N}(x_t^{(i)} - \bar{x}^{(i)})(x_{t-k}^{(j)} - \bar{x}^{(j)})}{\left[\sum_{t=k+1}^{N}(x_t^{(i)} - \bar{x}^{(i)})^2 \sum_{t=1}^{N-k}(x_t^{(j)} - \bar{x}^{(j)})^2\right]^{\frac{1}{2}}} \quad \text{i,j=1,2,3;·,n} \quad (4)$$

r_k^{ij} — the correlation coefficient between the variable series i and variable series j at the lag time k.

$\bar{x}^{(i)}$—the average value of variable series i.

$\bar{x}^{(j)}$ —the average value of variable series j.

The auto-regression coefficient is calculated with recurrence arithmetic.

$$\begin{cases} \hat{A}_{11} = \hat{\gamma}_1 \hat{\gamma}_0^{-1} \\ \hat{A}_{p+1,p+1} = (\hat{\gamma}_{p+1} - \sum_{j=1}^{p} \hat{A}_{pj}\hat{\gamma}_{p+1-j})(\hat{\gamma}_0 - \sum_{j=1}^{p} \hat{B}_{pj}\hat{\gamma}_j)^{-1} \\ \hat{A}_{p+1,j} = \hat{A}_{pj} - \hat{A}_{p+1,p+1}\hat{B}_{p,p+1-j} \qquad \text{j = 1,2,3,}\cdots\text{p} \end{cases}$$

and

$$\begin{cases} \hat{B}_{11} = \hat{\gamma}_1^{\tau} \hat{\gamma}_0^{-1} \\ \hat{B}_{p+1,p+1} = (\hat{\gamma}_{p+1} - \sum_{j=1}^{p} \hat{A}_{pj}\hat{\gamma}_{p+1-j})^{\tau}(\hat{\gamma}_0 - \sum_{j=1}^{p} \hat{A}_{pj}\hat{\gamma}_j)^{-1} \\ \hat{B}_{p+1,j} = \hat{B}_{pj} - \hat{B}_{p+1,p+1}\hat{A}_{p,p+1-j} \qquad \text{j = 1,2,3,}\cdots\text{p} \end{cases}$$

S_p —— the matrix of white noise variance. The estimated value $\hat{S}_p$ can be calculated as the following $\hat{S}_{p+1} = (I_k - \hat{A}_{p+1,p+1}\hat{B}_{p+1,p+1})\hat{S}_p$, I_k ——unit matrix of step k.

2.5 Build up multivariate auto-regression model

Because there is only one variable is regarded, and the system belongs to the condition of multi-input and multi-output, it is only the first row can be used to describe in the model. Thus, the complex issue can be simplified.

For example, if only regarded the crop water requirement, the series of water requirement can be taken as output, and the other meteorological factors are taken as input to build up forecasting model. The model is as follows.

$$\{x_t^{(1)} = a_{11}^{(1)}x_{t-1}^{(1)} + \cdots + a_{1p}^{(1)}x_{t-p}^{(1)} + a_{11}^{(2)}x_{t-1}^{(2)} + \cdots + a_{1p}^{(2)}x_{t-p}^{(2)} + a_{11}^{(n)}x_{t-1}^{(n)} + \cdots + a_{1p}^{(n)}x_{t-p}^{(n)} + \mathrm{b}_{11}^{(1)}\varepsilon_t^{(1)} + \mathrm{b}_{12}^{(2)}\varepsilon_t^{(2)} + \cdots + \mathrm{b}_{1n}^{(n)}\varepsilon_t^{(n)} \quad (5)$$

2.6 Forecast based on ARV (n) model (Du, 1991; Wang, 1999; Wang, 2000)

The multivariable auto-regression model can be established to forecast after calculating the parameters of models, and the formula (5) can be simplified. The forecasting model of one step is as follows.

$$\hat{x}_t^{(1)}(1) = \sum_{i=1}^{p} a_{1i}^{(1)}x_{t+1-i}^{(1)} + \sum_{i=1}^{p} a_{1i}^{(2)}x_{t+1-i}^{(2)} + \cdots + \sum_{i=1}^{p} a_{1i}^{(n)}x_{t+1-i}^{(n)} = \sum_{r=1}^{n}\sum_{i=1}^{p} a_{1i}^{(r)}x_{t+1-i}^{(r)} \quad (7)$$

3 Application Example

According to the above theory, ARV (6) model of rice water requirement in Fujin area can be established. The original data is from 1985 to 1999 (15 years).

Taking the rice water requirement (ET), daily mean air temperature (T), sunlight hours (h), saturation deficiency (d), wind velocity (u) and water evaporation, (E) are as input variables, and rice water requires (ET) as single output.

$X = \{x_i^{(1)}, x_i^{(2)}, x_i^{(3)}, x_i^{(4)}, x_i^{(5)}, x_i^{(6)} \quad i = 1,2,3,\cdots N\}$

In order to express, let: $x_i^{(1)}$ — ET, $x_i^{(2)}$ — T, $x_i^{(3)}$ — h, $x_i^{(4)}$ — u, $x_i^{(5)}$ — d, $x_i^{(6)}$ — E N —the content of sample. In this example, N =15(year)×6(stage)=90.

The well irrigation rice can be divided into six stages according to the rice growing period. Rice planting was around May 20th every year based on climate case in past years in Sanjiang Plain. Therefore, the stages are: rice planting stage (May 20-May 29, 10 days in total), returning green stage (May 30-Jun 5, 7 days in total), tillage stage (June 6-July 10，35 days in total), booting stage (July 11-July 20, 10 days in total), spiking and blooming stage (July 21-July 27, 7 days in total) and grain filling and mature stage (July 28-Agust 31, 35 days in total).[1]

3.1 Deal with the data

Firstly, by means of the following formulae the average of every variable series can be calculated.

$\bar{x}$={7.5499，19.8508，6.6947，3.1816，16.8096，5.9496}.

The variances are like this:

s^2={6.3272，10.2653，4.8898，0.4477，21.4653，2.0094}

Standardize the data series: $z = \frac{X - \bar{x}}{s}$

Here, the multivariate series have been converted to standardization series the average is zero.

3.2 Steady the series (pick-up the period items)

The sample series has no obvious trend items, but has period varied trend. The period is 12 months (one year). Therefore, the method of harmonic analysis is adopted.

Through calculating, only the fifth harmonic is significant in series $z^{(1)}, z^{(2)}, z^{(5)}$, and in series $z^{(3)}$. There are 7 harmonic belong to significant harmonic which are the number 1, 6, 8, 15, 30, 38 and 42. In series $z^{(4)}$, the number 1, 5, 15, 20, 29, 30, 35 and 45 are harmonic. In series $z^{(6)}$, the number 8, 15, 24, 28, 29, 30, 35, 38 and 45 are harmonic. The averages of every series equal zero. Therefore, takes $a_0 = 0$.

For example, picking up harmonic in series $z^{(1)}$.

$z_t^{(1)} = a_{15}^{(1)} \cdot cos(\frac{2\pi \times 15}{90}) + b_{15}^{(1)} \cdot sin(\frac{2\pi \times 15}{90}) + \varepsilon_t^{(1)}$. The

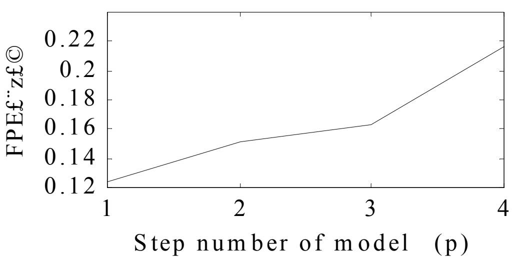

Figure 1 Step number of model

Thus, after deducting the period component, it can obtain the remained part named random series, and theARV(n) model can be established.

3.3 Calculate the correlation matrix and the step of model

At first, to inquire into the auto-correlation matrix, the covariance matrix can be obtained. Adopting the method of recurrence arithmetic, the matrix of $\hat{A}_{11}, \hat{A}_{p+1,p+1}, \hat{A}_{p+1,j}, \hat{B}_{11}, \hat{B}_{p+1,p+1}, \hat{B}_{p+1,j}$ can be obtained and the value of $FPE_p(z_t)$ is 0.1234，0.1510，0.1632，0.2170 correspondingly (Figure 1). According to Figure 1, the value of $FPE_p(z_t)$ is increasing from beginning and the define of the step model is 1. Therefore, the ARV（1，6）model can be expressed as follows.

$Z_t = A \cdot Z_{t-1} + B \cdot E_t$

3.4 Calculate Parameters

With the formula $\hat{A} = \hat{\gamma}_1 \hat{\gamma}_0^{-1}$ it can calculate the matrix $\hat{A}$, and multiply Z_t^T in the right side of formula and then to take into account the mathematical expectation.

$$E\left[Z_t Z_t^T\right] = \hat{A}E\left[Z_{t-1} Z_t^T\right] + \hat{B}E\left[\hat{E}_t Z_{t-1}^T\right]A^T + \hat{B}E\left[\hat{E}_t \hat{E}_t^T\right]\hat{B}^T .$$

Because $E\left[\hat{E}_t Z_{t-1}^T\right] = \phi$ $\quad$ $E\left[\hat{E}_t \hat{E}_t^T\right] = 1$（Unit matrix）, then

$\hat{\gamma}_0 = \hat{A} \cdot \hat{\gamma}_1^T + \hat{B} \cdot \hat{B}^T \Rightarrow \hat{B} \cdot \hat{B}^T = \hat{\gamma}_0 - \hat{A} \cdot \hat{\gamma}_1^T = \hat{\gamma}_0 - \hat{\gamma}_1 \cdot \hat{\gamma}_0^{-1} \cdot \hat{\gamma}_1^T$.

Based on software MATLAB5.3, the matrix $\hat{B}$ can be calculated.Because only the series of rice water requirement is taken consideration, rice water requirement forecasting model is established only.

$$z_t^{(1)} = \sum_{i=1}^{6} A_i^{(1)} \cdot z_{t-1}^{(i)} + \sum_{i=1}^{6} B_i^{(1)} \cdot E_t^{(i)}$$

$$= \begin{matrix} 0.1595 z_{t-1}^{(1)} - 0.0175 z_{t-1}^{(2)} - 0.1325 z_{t-1}^{(3)} - 0.0248 z_{t-1}^{(4)} \\ + 0.0892 z_{t-1}^{(5)} + 0.1181 z_{t-1}^{(6)} + 0.9834 E_t^{(1)} \end{matrix}$$

The average of residual error $E_t^{(1)}$ is as follows.

$\overline{E}^{(1)} = -0.00123 \to 0$.

Variance of $\sigma_{E^{(1)}}^2$ is 0.2455, $\sigma_{E^{(1)}} = 0.4955$.

$Q = N \sum_{k=1}^{m} r_k^2 (E^{(1)})$ =14.8648< $\chi_{0.05}^2 = 15.507$, （ $m = \frac{N}{10}$ =9） . The residual series is steady and independent.

Normal checking:

$$C_{sx^{(1)}} = \frac{1}{N-3} \sum_{i=1}^{N} (E_i^{(1)} - \overline{E}^{(1)}) / \sigma_{E^{(1)}}^{3/2} = 0.081 \to 0 .$$

So, the random residual is content to normal distribution: $E^{(1)} \sim (0, \sigma_{E^{(1)}}^2 = 0.2455)$.

3.5 Build up model

Adding the period item to the above model, and revert the standardized series, the following expression can be established.

$$z_t^{(1)} = a_{15}^{(1)} \cdot cos(\frac{2\pi \times 15}{90}) + b_{15}^{(1)} \cdot sin(\frac{2\pi \times 15}{90}) +$$
$$0.1595 z_{t-1}^{(1)} - 0.0175 z_{t-1}^{(2)} - 0.1325 z_{t-1}^{(3)} - 0.0248 z_{t-1}^{(4)}$$
$$+ 0.0892 z_{t-1}^{(5)} + 0.1181 z_{t-1}^{(6)} + 0.9834 E_t^{(1)}$$
$$x_t^{(1)} = s \cdot z_t^{(1)} + \overline{x}^{(1)} = 2.5154 \cdot z_t^{(1)} + 7.5499$$

3.6 Fit and forecast based on ARV (6) model

Now, taking ARV (6) model to fit the original rice water requirement series the curve is shown in Figure 2. From Figure 2, the curve of calculation fitting original series is rather good. Then, the relative error is calculated: $\xi_t = \left| \frac{\hat{x}_t^{(1)} - x_t^{(1)}}{x_t^{(1)}} \times 100\% \right|$. After calculating, the average relative error is 2.14%. The model has been used to forecast the rice water requirement in 2000 and the result is satisfied (Table 1, Fig. 3).

Table 1 The contrast table between the practical value and forecasting value of well irrigation rice water requirement (unit: mm/d)

		rice planting stage	returning green stage	Tillering	booting stage	spiking and blooming stage	grain filling and mature stage
2000	Practical value	4.63	5.81	8.84	10.73	9.35	6.32
	Forecasting value	4.7159	5.6351	8.6390	10.5809	9.4961	6.4658
	Relative error	+1.94%	-2.93%	-2.26%	-1.40%	+1.60%	+2.37%

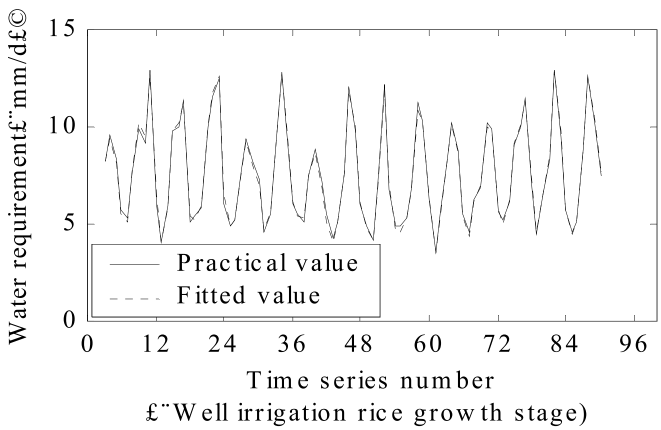

Figure 2 The curve fitted by multivariate auto-regression requirement model of water requirement of well irrigation rice

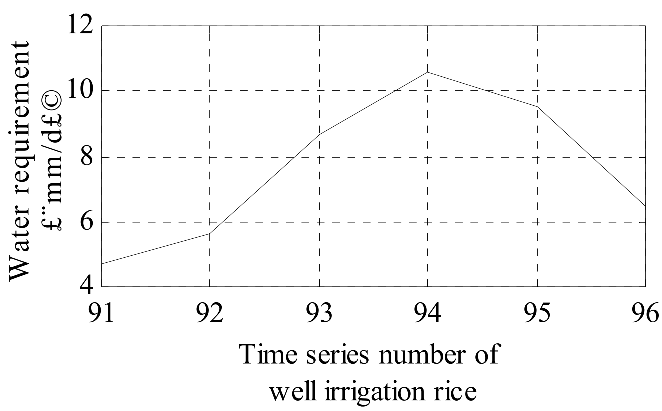

Figure 3 The curve of forecasting the water of well irrigation rice in 2000 (Fujin area, China)

3.7 Analyze the model

In order to consider whether the ARV (6) model can be replaced by part of components, such as marked the previous l component as $x_t^{(i)}(l)$, the sub-phalanx of the finally forecasted error is introduced.

$$FPE_{p,l,k}(x_t^{(i)}) = (1+\frac{kp}{N})^l (1-\frac{kp}{N})^{-l} \det(\hat{\gamma}_0 - \sum_{i=1}^{p} \hat{A}_{pi}\hat{\gamma}_j^{\tau})_l .$$

$(\hat{\gamma}_0 - \sum_{i=1}^{p} \hat{A}_{pi}\hat{\gamma}_j^{\tau})_l$——the sub-phalanx on the top left corner of $k \times k$ matrix ($\hat{\gamma}_0 - \sum_{i=1}^{p} \hat{A}_{pi}\hat{\gamma}_j^{\tau}$)

If $\min_p FPE_{p,l,k}(x_t^{(i)}) \geq \min_p FPE_{p,l,l}(x_t^{(i)}(l))$, no need to consider the setting up model by using k dimension time series ($\{x_t^{(i)}\}$), and only need to use the former l dimension series ($\{x_t^{(i)}(l)\}$). Therefore, from the point of view of the least finally error rule, taking k dimension series doesn't bring obvious benefit but only taking the former l dimension series into account. In other words, the function of the component of $l+1, l+2, \cdots, k$ is quite little. Therefore it is negligible. Contrarily,if it is $\min_p FPE_{p,l,k}(x_t^{(i)}) < \min_p FPE_{p,l,l}(x_t^{(i)}(l))$, the k dimension series must be taken into account.

According to the above analyzing, the model can be analyzed (Table 2).

Table 2 The table of finally forecasting error

p	k=6 l=1	k=6 l=2	k=6 l=3	k=6 l=4	k=6 l=5	k=6 l=6
1	0.9888	0.8442	0.5015	0.4964	0.2059	0.1234
p	k=5 l=1	k=5 l=2	k=5 l=3	k=5 l=4	k=5 l=5	
1	1.0111	0.8826	0.5361	0.5427	0.2302	
p	k=4 l=1	k=4 l=2	k=4 l=3	k=4 l=4		
1	1.0338	0.9228	0.5732	0.5933		
p	k=3 l=1	k=3 l=2	k=3 l=3			
1	1.0571	0.9648	0.6129			
p	k=2 l=1	k=2 l=2				
1	1.0809	1.0088				
p	k=1 l=1					
1	1.1053					

From Table 2, it shows when the dimension increases, the error reduces gradually. For example, if taking the rice water requirement into account, it means k=1 and l=1, and the error is 1.1053. If adding the dimension number, it means to consider the daily mean air temperature (k=2), and the finally forecasted error is 1.0809. If the dimension number increases continually, the error reduces step by step. When k=6 and l=1, the error is 0.9888. The error is the least error. Therefore, taking consideration of the meteorological factors is very important and necessary when establish the rice water requirement forecasting model.

4 Concluding Remarks

The author divide the well irrigation rice into 6 stages according to its growth phase, and make up of time series. At the same time, the author selects water requirement, daily mean air temperature, sunlight hours, daily mean wind speed, saturation deficiency and water evaporation as influential factors. By means of applying multi-dimension auto-regression model, the author took 6 dimension data series as input, and one dimension as output. Thus, the forecast of water requirement in the next growth stage can be calculated based on the every variable of the former stages. With analyzing, the author indicated that there were consanguineous relations among the 6 dimension variable series. Furthermore, the author established the ARV (6) model and put forward that the 6 influential factors are necessary for forecasting the rice water requirement. The fitting precision of ARV (6) model is fairly high, and the forecasted results are good. Therefore, the model can be applied to the area of well irrigation rice in Sanjiang Plain. Thus, with studying the ARV (6) model, the article provided scientific gist for water saving irrigation and saving groundwater resource. It can advance the sustainable agriculture and groundwater resource developing continually.

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