

# Analysis on Spatial and Temporal Variations of Maize Irrigation Water Requirement in Jilin Province

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**Abstract:** Based on the location of meteorological stations in Jilin Province, seven meteorological stations were selected. They are Fuyu, Yanji, Linjiang, Ji'an, Meihekou, Tongyu and Changchun. These meteorological data are from the year of 1984 to 2012. The meteorological data are analyzed by using crop coefficient method and water balance principle. The irrigation water requirement during the growth period of Maize in Jilin province was analyzed. The results show that: the average irrigation water requirement is 166mm in the middle of the dry year (75%) and in the drought year (90%). The variation range of irrigation water demand in each weather station is from 0 mm to 375mm. Regional differences are obvious. There is no obvious difference in irrigation water requirement in time. The variation characteristics of irrigation water demand of maize are increasing from east to west.

## 1. Introduction

Jilin Province is located in the world famous "golden corn belt". It is China's important commodity grain base. Corn acreage accounted for about 10% of the total area of the country. The total production and yields are ranked first in the country. It plays a decisive role in protecting the national food security. In the case of a serious shortage of water resources, the rational use of water resources is particularly important, especially for the growth of crops needed irrigation water. Therefore, it is of great significance to fully understand the temporal and spatial variation of crop water demand and the rational allocation of water resources.

Irrigation water requirement refers to the amount of irrigation water or water that is produced in addition to precipitation, to ensure the desired crop yield and quality, and to maintain the corresponding salt balance in the crop area. The calculation process is closely related to crop water demand. Since the beginning of the 19th century, the United States, Britain, France, Japan, Russia and other countries began to use a simple cylinder test method and field measurement method to observe the crop water demand. By the end of the 19th century, crop water demand experiments were progressively carried out in various countries. From the late 1940s to the early 1970s, it was the in-depth development period of crop water demand research. The crop water demand was measured by the measurement of Pit measurement and lysimeter. British scholar Penman published a calculation of the surface evaporation, bare land and pasture evaporation formula in 1948 in the Royal Society published. It is still the main method of calculation the wet under the surface evaporation. In 1963 Penman -Monteith (P-M) formula were produced by introducing the concept of surface resistance.



The crop water demand in domestic is later. The evaporation was measured on the farmland by water balance method. The results were analyzed for crop water demand and water consumption Foundation. In the case of water management in irrigation areas, the water use plan for irrigation areas was started according to the forecast of water supply and water demand. In the 1970s, computer technology, remote sensing and telemetry began to be applied to crop water research. Some new instruments were used to observe soil moisture content, and the water balance method was gradually improved. In the 1980s, the water holding characteristics of soil and the dynamics of water movement and its numerical simulation were studied. In the mid-1990s, Chen Yu-min system explored the water demand of the main crops in China and mapped out the national crop water demand contours. At the same time, the changes of water demand in space and time were analyzed.

## 2. Materials and methods

### 2.1. Experimental cite

Jilin Province is located in the northeastern part of China. Longitude is between  $121^{\circ} 38'$  and  $131^{\circ} 19'$ , latitude is between  $40^{\circ} 50'$  and  $46^{\circ} 19'$ . The length of east-west is 769.62 kilometers, the width of north-south is 606.57 kilometers, and the land area is 187,400 square kilometers, accounting for 2% of the country's area. Jilin Province has fertile land. The soil surface organic matter content of 3% to 6%, high more than 15%. It has the favorable conditions of development of efficient and green agriculture.

There are many meteorological stations in Jilin Province. After studying the terrain characteristics and climatic characteristics of Jilin Province, this paper selected seven meteorological stations. These are Fuyu, Yanji, Ji'an, Linjiang, Meihekou, Tongyu and Changchun. The data sources of the site are Jilin Meteorological Bureau. The weather data included sunshine hours, average wind speed, relative humidity, precipitation, minimum and maximum temperature, dimension and altitude. The following table 1 shows the altitude and latitude of seven meteorological stations.

**Table 1** Altitude and latitude of meteorological stations

Meteorological station	Altitude (m)	Latitude (°)
Fuyu	180	45.1
Yanji	175	42.9
Ji'an	180	41.1
Linjiang	342	41.8
Meihekou	320	42.5
Tongyu	147	44.8
Changchun	219	43.8

### 2.2. Research methods

According to the meteorological data of the selected stations from 1984 to 2012, the reference crop water requirement ( $ET_0$ ) was calculated according to the Penman formula, and then the crop water requirement ( $ET_m$ ) was calculated according to the crop coefficient method. Finally, the maize irrigation water requirement was calculated according to the water balance principle.

**2.2.1. Calculation of crop water requirement.** In this paper, the reference crop evapotranspiration was calculated using the Penman-Montessori formula. The formula is as follows.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

Where:

$R_n$  — the canopy surface of the net radiation, the reflection coefficient  $\alpha$  is 0.23;

$G$  — the soil heat flux, its value is ignored;

$T$  — the daily average temperature;

$e_s$  — saturated vapor pressure;

$e_a$  — the actual water vapor pressure value;

$\Delta$  — saturated water vapor pressure and temperature curve The tangent slope at the place;

$\gamma$  — the hygrometer constant;

$u_2$  — the average daily wind speed at 2m height.

The formula for calculating crop water demand is as follows.

$$ET_m = K_c ET_0 \quad (2)$$

Where:

$ET_0$  —reference crop evapotranspiration, mm / d;

$K_c$  — crop factor;

$ET_m$  — crop water requirement, mm.

**2.2.2. Calculation of irrigation water requirement.** This paper uses the water balance method to calculate the crop irrigation water requirement. According to the water index and water demand, crop water use was calculated day by day. The formula is as follows.

$$W_t - W_0 = W_r + P + I - ET_m - D \quad (3)$$

Where:

$W_0$  —the amount of water in the depth of the planned wetting layer at the beginning of the period, mm;

$W_t$  —the amount of water in the depth of the planned wetting layer at the end of the period, mm;

$W_r$  —the increased water in the unit area due to the increase the depth of the planned wetting layer, mm. In this paper, the depth of the planned wetting layer is consistent, that is, the value is zero.  $P$  — the effective amount of infiltration per unit area for the period, mm;

$I$  —the amount of irrigation per unit area for the period, mm;

$ET_m$  —the amount of crop water required for the period, mm;

$D$  —the amount of leakage per unit area planned for the period of time, mm.

$W_t$  can be calculated by the method of subsided index based on the daily precipitation indicators and crop water demand. The formula is as follows.

$$W_t = W_0 e^{\left(-\frac{ET_m}{W_j}\right)} + P \quad (4)$$

Where:

$W_j$  —the critical soil water storage capacity, mm;

$P$  —the period of time per unit area of effective precipitation, mm;

The remaining symbols are the same as before.

**2.2.3. Determination of irrigation indicators.** The total growth period of maize was 138 days. According to the law of maize growth and development, the irrigation control index was set up according to the actual situation of local planting. Table 2 shows that the root control depth is 100cm, and the corresponding water retention rate is 24.1%. The upper limit of irrigation is the same as that of

the area, and the lower limit of irrigation is 60% -66% of corresponding water retention rate, due to the different fertility stages.

**Table 2** Maize irrigation control indicators in Jilin province

Growth period	Sowing- three leaves	Three leaves - jointing	Jointing - grouting	Grouting - harvesting
Starting and ending date	5.5—5.25	5.26—6.25	6.26—8.8	8.9—9.19
Root depth (cm)	100	100	100	100
Field water holding capacity (v%)	24.1	24.1	24.1	24.1
Upper limit of irrigation (v%)	24.1	24.1	24.1	24.1
Lower limit of irrigation (v%)	14.9	15.2	15.9	14.46
Days of growth (d)	30	31	20	31
Kc	0.64	0.64-1.13	1.13	1.13-0.57
Irrigation quota(mm)	75	75	75	75

### 3. Results and analysis

#### 3.1. Time Variation of Irrigation Water Requirement in Maize

*3.1.1. Changes of Irrigation Water Requirement of Growth Period in Typical Year.* This paper statistic the precipitation of corn growth year by year, then calculated the frequency. The same as or similar to precipitation were chosen. The year of rainfall distribution is not conducive to the year of maize growth as the typical year of design. A typical year of design with a rainfall frequency of 75% (medium dry years) is selected. The calculation results of maize irrigation water demand are shown in Table 3.

**Table 3** Jilin Province medium dry years (75%) irrigation system

Typical station	Hydrol- ogical typical year	Typical year	P (mm)	ET <sub>m</sub> (mm)	Irrigation quota (mm)	Irrigation frequency	Irrigation date (Days after sowing)
Fuyu	75%	2004	297.5	492.5	225	3	7、35、70
Yanji	75%	1988	324.4	391.4	150	2	13、102
Ji'an	75%	1988	481.1	441.0	0	0	
Linjiang	75%	2001	392.3	397.9	75	1	45
Meihekou	75%	2000	423.4	428.7	75	1	8
Tongyu	75%	1995	254.7	629.0	375	5	6、31、45、63、71
Changchun	75%	1999	389.5	559.4	225	3	8、40、69

It can be seen from Table 3 that the irrigation water demand in Tongyu area is the highest in the seven dry is not need irrigation. The irrigation water demand in both the Linjiang and Meihekou was 75mm, but the irrigation time was different. The date of irrigation was 45 days and 8 days after sowing respectively. Fuyu and Changchun irrigation water demand are the same. It is 225mm, and the two regions each time the irrigation is also close. Yanji area irrigation water demand is 150mm. Irrigation water demand is basically showing the gradually increase change from east to west.

*3.1.2. Irrigation Water Requirement for Typical Year Growth Stage of Maize.* The irrigation situation of maize in 75% typical year is shown in Table 4.

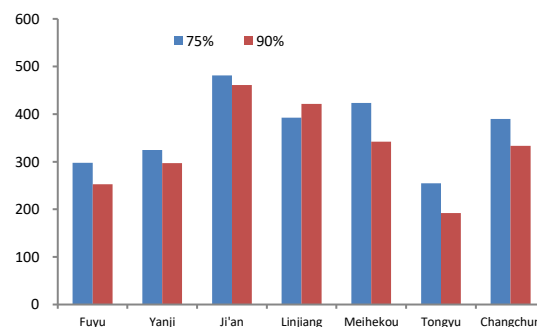
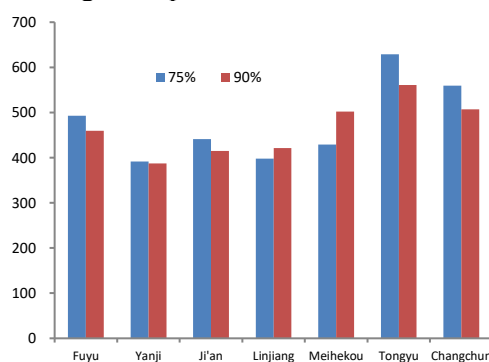
**Table 4** the irrigation quota during different growth period in the frequency of 75% (mm)

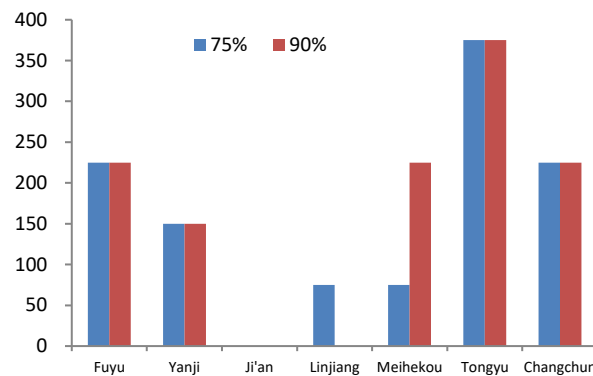
Typical station	Sowing three leaves	Three leaves ointing	Jointing grouting	Grouting harvesting
Fuyu	75	75	75	
Yanji	75			75
Linjiang		75		
Meihekou	75			
Tongyu	75	150	150	
Changchun	75	75	75	

From Table 4, it can be seen that the irrigation time of maize in Jilin area is mainly concentrated in three stages: three leaves, jointing and grouting stage. Tongyu station irrigation volume is large, in the jointing and grouting stage are filling 2 times. Ji'an station does not need irrigation, because the local rainfall is large, it can meet the growth of corn. Yanji area irrigation water demand is mainly concentrated in the three leaves, grouting two stages, and the total of irrigation water needs 150mm. The irrigation water demand in Linjiang is in the joint stage, and the irrigation water demand is 0 in other stages. Mei irrigation area irrigation water demand in the three leaf stage, other stages of irrigation water demand is 0.

### 3.2. Spatial Variability of Irrigation Water Requirement in Maize

This paper analyzed the maize crop water demand, effective precipitation and irrigation quota in different typical annual growth period in Jilin province. And then it analyzed the change of irrigation water demand in maize. Ji'an station with the largest effective precipitation in 75% and 90% of the typical years was 481 mm and 461 mm, respectively. Tongyu station with the smallest effective precipitation was 254 mm and 192 mm, respectively. In the 75% and 90% of the typical years of irrigation quota for the largest area of Yuanyu were 375mm and 375mm, the minimum value for the set of irrigation quota is 0. The chart is shown in Figures 1to Figures 3.

**Fig. 1** Corn water requirement (ETm) of each station in typical years**Fig. 2** Effective precipitation (Pe) of each station in typical years



**Fig. 3** Irrigation water of each station in typical years

#### 4. Conclusions Results and analysis

Based on the meteorological data of Jilin Province from 1984 to 2012, the irrigation water demand of maize in Jilin Province was analyzed. The average annual irrigation water requirement of the seven meteorological stations in Jilin Province was 166 mm during the whole drought period (75%) and the drought year (90%). The variation range was from 0 mm to 375 mm, and the regional difference was obvious. The difference of time change characteristics of irrigation water requirement in Jilin Province was not obvious. The irrigation water demand in the space showed the spatial variation characteristics of the east and west, and gradually increased from east to west. Precipitation, sunshine hours and temperature are important factors influencing the temporal and spatial changes of irrigation water demand in maize.

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