Research on building water usage norms for field surface irrigation at irrigation works exploitation units in Lam Dong province, Vietnam

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Abstract

The economic and technical norms in the management, exploitation and protection of irrigation works are the basis for planning, verifying and appraising production plans, annual financial plans and final settlement such as the cost of management, exploitation and protection of irrigation works. Type of works, quantity, technical parameters, current status of works and equipment, irrigation tasks, technology, etc., of each irrigation enterprise has applied different technologies. Therefore, the cost of materials, fuel and labor for the management and operation of the construction system of each enterprise is also different. We cannot use the norm of one business to apply to another. In order to match the actual situation, improve the efficiency of management, exploitation and protection of irrigation works, it is necessary to establish norms for using water for irrigation of fields. This study develops norms of water usage for irrigation of fields in the exploitation units of irrigation works in Lam Dong province to meet the above mentioned problems.

Keywords: *Water usage norms, irrigation works, Lam Dong province.*

1. Introduction

The norm of water usage is the total maximum amount of water used per production unit, which is sufficient to ensure the normal growth and development of cultivated plants and aquatic products. Water taken from irrigation works is mainly for agricultural production and aquaculture, so the unit for calculating the norm of water usage is usually in m3/ha-crop in the field. The norm of water usage is calculated based on the conditions of land, soil, weather conditions and growth and development characteristics of crops and aquaculture species.

Water usage norms are developed for two main users: water for irrigation of rice, vegetables, fruit trees and water for aquaculture. Other types of users calculate the conversion of rice water usage.

The water usage norm is calculated corresponding to the year with seasonal rainfall according to the provisions in. Specifically, it is calculated with the service guarantee level of the irrigation works P=85%.

Therefore, it is necessary to study and develop norms of water usage for irrigation of fields at irrigation works exploitation units in Lam Dong province, thereby serving as a basis for these units to implement annually.

In the study, the calculation of the content of formulating the norm of water usage for field irrigation follows the following steps:

Step 1. Collect, analyze and synthesize documents and data.

Step 2. Calculate the water usage norm. Use methods: Moment Method, Appropriate Method, Three Point Method.

Research scope:

Content: Developing norms for using surface water in the field at the units exploiting irrigation works.

Time: from January 2019 to December 2022.

Location: The units exploiting irrigation works in Lam Dong province.

2. Research results

2.1. Establishing norms of water usage for irrigation of fields at the management and exploitation units of irrigation works in Lam Dong province

Step 1. Collect, analyze and synthesize documents and data

- Statistics of irrigation areas, irrigation zones, structure of plants and animals (rice, crops, aquatic species, etc.), cultivation schedule, seasons.

- Collecting, making statistics and synthesizing documents on hydrometeorology, soil documents of the irrigated area.

- Based on hydro-meteorological conditions, soil properties and water users, classifying and zoning similar conditions to build norms.

Step 2: Calculate the water usage norm

Rain data: List the daily rainfall data of the meteorological station with the number of years n = 20 years.

The seasonal rainfall corresponds to the design frequency and is calculated based on the construction of the rain frequency curve.

The calculation sequence is as follows:

(1) Statistics of seasonal rainfall from the rain data collection table:

Xvụ i (i=1,2,3,4,…)

(2) Calculate the average rainfall of many years:

Xbqvụ = 1/n . Σ Xvụ i (i=1,2,3,…..)

(3) Calculate frequency of experience:

Pm = (m-3)/(n+4).100% (1)

In which: Pm - frequency of experience, corresponding to the value of X-case m ranked at the mth position, after sorting from large to small.

n - the number of years with the selected rainfall for the calculation.

(4) Draw the experience frequency line

Based on the relation Xservice m ~ Pm%

(5) Calculate the parameters (Xbq, Cv, Cs) and plot the reasoning frequency line.

After calculating the parameters (Xbq, Cv, Cs), choose the appropriate method of plotting the frequency line from the following methods:

a) Moment method

The basis of this method is that the statistical characteristics: Cv, Cs calculated from the series of real measured data X1,..., Xn are the corresponding statistical characteristics of the population.

Then we hypothesize some probability model, check the fit between the hypothesized probabilistic model with the real data series measured by statistical method. If satisfactory, we can use the model to calculate Xp.

$X_p = (\Phi_p . C_v + 1). \overline{X}$ (2)

In there:

Xp - the seasonal rainfall corresponding to the probability P

Φp - function depends only on Cs and P- Tính hệ số phân tán C_v:

$$C_v = \frac{1}{\overline{X}}\sqrt{\frac{(X_i - \overline{X})^2}{n-1}} = \sqrt{\frac{\sum (k_i - 1)^2}{n-1}} \qquad (3)$$

- Calculate the coefficient of bias Cs:

$$C_s = \frac{\sum_1^n (K_i - 1)^3}{(n-3).C_v^3} \qquad (4)$$

The moment method gives objective calculation results, but encounters unexpected points that cannot be handled and often gives small biased results when calculating statistical features. The moment method is only suitable in the case of complete data.

b) Appropriate method

Unlike the Moment method, the appropriate method assumes that it is possible to change the statistical characteristics Cv, Cs to a certain extent so that the hypothetical probability model is est uited to the real data series.

Calculate the average rainfall $\overline{X}$:

$$\overline{X} = \frac{1}{n}.\sum_{i=1}^{n} X_i \qquad (5)$$

Calculate the moduls factor:

$$K_i = \frac{X_i}{\overline{X}} \qquad (6)$$

Calculate the dispersion coefficient Cv:

$$C_v = \frac{1}{\overline{X}}\sqrt{\frac{(X_i - \overline{X})^2}{n-1}} = \sqrt{\frac{\sum (k_i - 1)^2}{n-1}} \qquad (7)$$

Calculate the coefficient of bias Cs:

$$C_s = \frac{\sum_1^n (K_i - 1)^3}{(n-3).C_v^3} \qquad (8)$$

The appropriate method gives us an intuitive concept, easy to comment and handle unexpected points. However, the assessment of the appropriateness between the theoretical frequency curve and the empirical frequency line depends on the subjectivity of the operator.

c) Three point method

Like the appropriate method, the three-point method also takes the fit between the theoretical frequency line and the empirical frequency line as a standard. However, in other parameters Cv, Cs are calculated according to 3 preselected points, of which P2 = 50% and points P1 and P3 are symmetrical through P2.

The three-point method has the advantage of fast and simple calculation, but it also has the disadvantage of depending on the subjectivity of the implementer and the choice of 3 points…

d) Method Selection

Based on the advantages of the appropriate method, in this study we choose the appropriate method with Pearson III probability distribution model for calculation.

Calculate the seasonal rainfall corresponding to the basic frequencies

On the theoretical frequency line drawn according to the selected method, the total rainfall in crop Xcrop corresponding to the frequency P = 25%, 50%, 75%, 85% (corresponding to year, heavy rain, average rain, and little rain, respectively).

Application of hydrological calculation software "FFC2008" of author Nghiem Tien Nam – Thuyloi University.

(6) Select the Rainy Season Model

The representative rainfall model selected in the list of monitoring years ensures the following requirements:

- There are rainy day material;

- The selected rain model must be a rain model that has occurred in reality, which means it must be in the monitoring document and is likely to occur in the future;

- The combination of rainfall in the season is relatively unfavorable (rainfall in the period of urgent water demand is less concentrated on a few days);

- The selected rain model must have the actual total rainfall of the crop approximately equal to the rainfall corresponding to the design frequency P%.

- We can choose the design rain model in the following two cases:

The most unfavorable model: That is, choose the driest year, the least rain but the most water needed. When choosing this model, the water supply capacity is safe.

Model frequently appears: When choosing according to this model, the works often work at full design capacity, the works have high efficiency. However, the year with little rain will cause water shortage.

The results of selecting typical annual rainfall correspond to the design frequency of 85%.

(7) Crop rain pattern zoom

Since the typical rainfall is different from the design rainfall (P% = 25%, 50%, 75%, 85%) we must re-scale the typical rain pattern using one of the following two methods.

Zoom method with the same ratio: this is suitable for typical rain and the rainfall of the whole game is the design rainfall.

Same-frequency zoom method: this is suitable for a design rain of the same amount of rain, along with a short period corresponding to the design frequency. But the coefficients K1, K2, K3, …, Kn are different, the shape of the rain is not preserved.

In this norm, because it is calculated for the rainy season and it is necessary to have a model of the rain occurring in reality, we choose the zoom method with the same ratio (typical rains are attributed to the design rain). Based on the X values of 25%, 50%, 75%, 85% and the values of Xdh selected above and based on the existing data, we proceed to zoom the rain data for the crops according to the following steps::

Zoom factor Kp:

$$K_p = \frac{X_{vuP\%}}{X_{vudh}} \qquad (9)$$

$X_{vụ\ p\%}$ - the seasonal rainfall corresponding to the basic frequencies (mm).

$X_{vụ\ dh}$ - typical crop rainfall (mm).

From the typical rain pattern results, zoom in on the rain pattern for each crop.

2.2. Calculate the amount of water evaporated

The amount of surface evaporation is affected by many different factors, so it is relatively difficult to determine accurately. Therefore, the general principle in the methods of determining the amount of field evaporation is to analyze the relationship between the amount of surface evaporation with the main and important influencing factors. From there, through those factors, we find a formula to calculate the amount of field evaporation ETc.

The actual amount of field evaporation for a given crop is determined by the general formula:

$$ET_c = K_c . ET_o \quad (10)$$

In there:

ET_c: Actual amount of evaporation according to calculation time

ET_o: Reference evaporation (standard evaporation) is calculated according to formulas based on experimental results under certain defined conditions..

K_c: Crop coefficient, which depends on the type of crop and the growth stages of the crop, is determined experimentally.

ntally.

2.2.1. Calculation of potential evapotranspiration (ETo)

Potential evapotranspiration (ETo) is the capacity to evaporate under conditions that are not limited by soil and plant moisture but are dependent only on climatic conditions (temperature, humidity, wind speed and light hours).

To determine the water usage in the field (water demand in the field), we have methods:

(1) The formula for calculating field surface evaporation is based on the amount of free water surface evaporation (referred to as the □ coefficient method): simple, based only on the evaporation of the open water surface.

(2) The method of taking crop yield as a basis (called the K coefficient method): Considering the factor of crop yield. This method is for reference only and is rarely used at present.

(3) Charov method: Considering the relationship between the amount of field surface evaporation and the total average daily temperature according to the growth stage of the crop.

(4) Thornthwaite method : The calculation system depends only on the temperature.

(5) Blaney – Criddle method: Considering many factors that directly affect, mainly climate factors.

(6) Radiation formula: Considering the relationship with solar radiation, temperature and altitude of the irrigation area.

(7) PenMan formula: Considering 4 main climatic factors are temperature, humidity, wind speed and hours of sunshine and rain. According to experts, the Penman method considers the most climatic factors and often gives the most realistic result

Each method has certain advantages and disadvantages in different application conditions. To determine the use of water for irrigation in the field of crops (field water demand), according to the World Food and Agriculture Organization (FAO), Vietnam should apply the Penman method. This method has mentioned the following factors: rain, temperature, humidity, evaporation, wind speed and sunshine hours in accordance with Vietnam's climate conditions.

The rationale is reliable and high calculation accuracy can quantify reference evaporation from 1 day to 1 month. If there is a correction, it can be calculated by the hour. Penman's formula is studied and corrected through many practical cases, therefore, many formula forms have been found.

The formula has the form:

$$ET_o = C[WR_n + (1-w)f(u)(e_a - e_d) \quad \text{(mm/day)} \quad (11)$$

ETo = C[WRn +(1-w)f(u)(ea-ed) (mm/day)

In there:

W: Effectiveness correction factor of radiation for evaporation due to temperature and height of irrigation zone, W = f (temperature, height of irrigation zone).

Rn: Difference between increased radiation and decreased radiation of short and long waves (mm/day)

$$R_n = R_{ns} - R_{nL} \quad (12)$$

R_{ns}: The radiation of the sun is retained after it has been reflected to the cultivated ground (mm/day)

$$R_{ns} = (1 - \alpha)R_s \quad (13)$$

α: The surface reflectance coefficient of the cultivated area, according to FAO, is $\alpha = 0,25$

R_s: Solar radiation (mm/day)

$$R_s = \left(0,25 + 0,5\frac{n}{N}\right)R_a \quad (14)$$

R_a: Radiation at the boundary layer of the atmosphere (mm/day), Ra = f(latitude, month)

R_{nL}: Radiation emitted by the initial absorbed energy (mm/day)

$$R_{nL} = f(t)f(e_d)f\left(\frac{n}{N}\right) \quad (15)$$

f(t): Correction function for temperature:

$$f(t) = \frac{118(t+273)^4 10^{-9}}{L} \quad (16)$$

with $L = 59,7 - 0,055t$ (17)

t: average daily temperature

$f(e_d)$: Correction function for barometric pressure

$$f(e_d) = 0,34 - 0,044\sqrt{e_d} \quad (18)$$

e_d: Actual steam pressure at mean air temperature (mbar)

f(u): Correction function for wind speed

$$f(u) = 0,35(1 + 0,54U_2) \quad (19)$$

U_2: Wind speed at a height of 2m, when other than 2m must be adjusted. Therefore, when calculating using the formula:

$$U_2 = KU_h \quad (20)$$

U_h: Wind speed at height h meters (m/s)

K: Correction factor < 1 if wind measurement location is more than 2m

$$f\left(\frac{n}{N}\right) = \left(0,1 + 0,9\frac{n}{N}\right) \quad (21)$$

e_d is determined:

$$e_d = e_a\frac{H_r}{100} \quad (22)$$

e_a: Saturated steam pressure, related to air temperature;

H_r: Average relative humidity of the air (%)

C: Correction factor for the compensation of daytime and nighttime wind speeds as well as variations in solar radiation and maximum relative humidity of the air.

CropWat 8.0 software application for calculation. Cropwat software that calculates water demand and manages irrigation of the World Food and Agriculture Organization (FAO) has been widely applied in countries around the world since 1992. It is the authoritative software, the highest international force today. Software - the first program is Cropwat Verson 5.7 which has also been used in Vietnam for many years, developed and improved into Cropwat Version 7.0 (1995) and Cropwat 4.3 (1998). Currently, it has been improved and upgraded to Cropwat 8.0, suitable for use in many environments such as windows XP, windows 7,8, etc. Functions of the program:

Calculate the amount of evaporation - the amount of water needed by the crop;

Calculate the water requirement of each plant and the whole group of crops;

Calculation of demand, irrigation regime and management of field surface irrigation for crops under different conditions. This calculation is based on reliable ground water balance and soil - water - crop and climate relationship..

2.2.2. Calculation of crop evapotranspiration (ETc)

The amount of evapotranspiration of plants is calculated according to the formula:

$$ET_c = K_c \cdot ET_o \quad (23)$$

In there:

K_c: The crop factor depends on the type of crop, the growth stage of the crop and the climatic characteristics of the region (mm/day, week or month).

ET_o: standard evapotranspiration (mm/day, week or month).

2.3. Calculation of water usage norms for field irrigation

The norm of water usage in the field is determined according to the equation:

$$M = LP + M_{td} \ (m^3/ha - vụ) \quad (24)$$

In there:

M : Irrigation level for the whole crop

LP : Amount of water for irrigation during tillage period before sowing

Mtd ¬¬: Amount of water to irrigate during the growing period

2.3.1. Amount of water to irrigate (to prepare the soil) before sowing (LP).

a) Amount of water to irrigate the soil before sowing for rice

General formula for determining the amount of water before sowing:

$$LP = W_1 + W_2 + W_3 + W_4 - 10CP \quad (25)$$

In there:

- W1: The amount of water required to saturate the arable soil is determined as follows:

$$W_1 = 10.A.H.(1- \beta_0) \quad (m^3/ha) \quad (26)$$

+ The dimensional conversion factor here is 10;

+ A: Soil porosity as % by volume of soil according to soil mechanical composition;

+ H: Depth of arable soil layer from field surface to saturated soil layer (mm);

+ β_0: Initial humidity in % of A

- W_2: Amount of water needed to form the field surface water

$$W_2 = 10.a \ (m^3/ha) \quad (27)$$

+ The Dimensional Transformation Factor is 10;

+ a: Depth forms the surface water layer for tillage. This depth depends on the method of tillage, which can be used in monitoring and field survey documents to be included in the calculation..

- W_3: The amount of water infiltration is stable

$$W_3 = 10.K \frac{H+a}{H}(t_a - t_b) \ (m^3/ha) \quad (28)$$

In there:

+ The dimensional transformation coefficient is 10;

+ a : Depth to form field surface water for tillage;

+ t_a: tillage time (ngày);

+ t_b: saturation time of arable land. In fact, the arable soil layer is usually less than 1m, so the time to saturate the arable soil layer is not long and can be ignored or can be evaluated by experiment or empirically evaluated by field observations.

+ H: The depth of soil layer from the field surface to the saturated soil layer (m), this value is determined by experiment;

+ K: Infiltration coefficient of soil (mm/day), stable infiltration coefficient varies by soil type.

- W_4 : Amount of evapotranspiration

$$W_4 = 10.\ e.\ t_a\ (m^3/ha) \qquad (29)$$

+ The dimensional transformation coefficient is 10;

+ e: intensity of surface evaporation during tillage period is determined by average evaporation over many years (mm/day).

+ t_a: tillage time (ngày),

+ 10 CP: Amount of rainwater used during tillage

+ The dimensional transformation coefficient is 10;

+ P: is the total amount of rainwater falling during tillage determined from hydrological calculations.

C: coefficient of rainwater use calculated by the formula:

$$C = \frac{P_0}{P} \qquad (30)$$

In there:

P0: the amount of rainwater used that does not have to be removed. This amount of water is determined based on the actual conditions of the soil water layer requirements. Normally, only the surface water layer should be allowed to reach the maximum value in the irrigation formula for growth;

P: is the total amount of rainwater falling during tillage determined from hydrological calculation.

b) Amount of water to irrigate during the growing period

* Amount of water to irrigate the growing period of rice

The amount of irrigation water during the period of growth, development and harvest of rice is determined according to the equation of surface water balance in the calculation period. The equation has the following form:

The basic equation to determine the irrigation regime for rice plants:

$$h_{ci} = h_{0i} + \sum m_i + \sum P_{0i} - \sum K_i - \sum ET_{ci} - \sum C_i \qquad (31)$$

In there:

h_{ci} - Surface water layer at the end of the calculation period (mm);

h_{0i} - Surface water layer at the beginning of the calculation period (mm);

$\sum m_i$ - amount of water for irrigation during the calculation period (mm);

$\sum P_{0i}$ - amount of rainwater in the calculation period (mm);

$\sum K_i$ - amount of water infiltrating into the ground during the calculation period (mm/ngày);

$\sum ET_{ci}$ - the amount of evaporation in the field during the calculation period (mm/ngày);

$\sum C_i$ - amount of water removed during the calculation period. When the surface water layer of the field is larger than the allowable water depth, so $\sum C = h_i - h_{maxi}$.

The constraint condition of the above equation is:

$$[h_{min}]_i \leq h_{ci} \leq [h_{max}]_i \qquad (32)$$

In order to gradually solve the above equation, we proceed to solve according to the analytical method (tabulation) as the principle above. We divide the growth period of rice into many small periods, specifically here it can be calculated for the period of 1 day. In each of those periods, the known values are the surface water layer at the beginning of the period, the amount of water loss (due to infiltration and evaporation of the field surface), the amount of rain. Assuming 1 value of irrigation level m, then using the water balance equation to calculate the surface water layer at the end of that period. Compare this layer of water according to the formula for irrigation, if it is found suitable, it proves that m hypothesis is suitable. And if it is not suitable, we must assume m again. Specifically as follows: If for m the hypothesis can be calculated hc < [hmin], then assume m again by increasing m and redefining hc until it is satisfied according to the growth formula.

If with m assumptions we can calculate hc > [hmax], then assume m again by reducing m until the hyperplasia formula is satisfied.

In the case that m = 0 and hc > [hmax], we have to reduce the amount of rainwater and keep only 1 layer of water in the field equal to [hmax]. The amount of removal in water is calculated without subtracting [hmax].

Carrying out until the end of the growing period of rice, we will determine the following parameters: number of times to irrigate rice, watering rate each time, total watering rate of the whole crop, total water loss due to infiltration and evaporation of the field surface, total rainfall and total runoff during the whole season.

The results of calculating the norms of surface water usage in the irrigation works in Lam Dong province are shown in the table below.:

Table of results of calculation of norms of water usage for irrigation of fields in Lam Dong province

Number	District	Plant types	Irrigation norms (P = 85%)		
			Winter-spring crop	Summer-Autumn crop	Main crop
1	Bao Lam	Rice	8.431	4.727	3.041
		Flowers and vegetables	1.801	-	-
		Seafood	30.259	10.380	8.447
		CAQ, CCN			2.686
2	Bao Loc	Rice	8.772	5.198	3.203
		Flowers and vegetables	1.801	-	-
		Seafood	30.709	10.990	9.057
		CAQ, CCN			2.686
3	Cat Tien	Rice	7.933	5.149	2.763
		Flowers and vegetables	1.801	-	-
		Seafood	30.169	10.258	8.325
		CAQ, CCN			2.686
4	Da Hoai	Rice	9.029	5.345	3.359
		Flowers and vegetables	1.801	-	-
		Seafood	30.799	11.112	9.179
		CAQ, CCN			2.686
5	Da Lat	Rice	10.875	6.906	5.368
		Flowers and vegetables	2.187	557	754
		Seafood	29.763	13.107	12.524
		CAQ, CCN			2.924
6	Da Teh	Rice	8.090	4.706	2.820
		Flowers and vegetables	1.801	-	-
		Seafood	30.349	10.502	8.569
		CAQ, CCN			2.686
7	Dam Rong	Rice	11.048	7.078	5.540
		Flowers and vegetables	2.187	557	754
		Seafood	29.763	13.107	12.524
		CAQ, CCN			2.924
8	Di Linh	Rice	7.667	4.833	2.747
		Flowers and vegetables	1.801	-	-
		Seafood	30.079	10.136	8.203
		CAQ, CCN			2.686
9	Don Duong	Rice	11.112	7.033	5.970
		Flowers and vegetables	2.187	557	754
		Seafood	29.943	13.351	12.768
		CAQ, CCN			2.924
10	Duc Trong	Rice	11.296	7.167	6.009
		Flowers and vegetables	2.187	557	754
		Seafood	30.123	13.595	13.012
		CAQ, CCN			2.924
11	Lac Duong	Rice	10.907	6.918	5.399
		Flowers and vegetables	2.187	557	754
		Seafood	29.763	13.107	12.524
		CAQ, CCN			2.924
12	Lam Ha	Rice	10.428	6.339	5.121
		Flowers and vegetables	2.187	557	754
		Seafood	29.583	12.863	12.280
		CAQ, CCN			2.924

3. Conclusion

Through the calculation of the norms of water usage for irrigation of fields in the exploitation units of irrigation works in Lam Dong province, it is in accordance with the current regulations. The obtained research results can be fully applied to the mining units of irrigation works in Lam Dong province for operation in the following years, which is the basis for contract work as well as payment and settlement.

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