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MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT
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STUDY ON BUILDING THE OPTIMAL SOLUTION OF IRRIGATION WATER STORAGE TO MINIMIZE THE EFFECT OF DROUGHT ON AGRICULTURAL PRODUCTION IN DOWNSTREAM CA RIVER – CASE STUDY IN LE XUAN DAO IRRIGATION SYSTEM

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INTRODUCTION

1. Necessity of the thesis

Currently, studies related to the efficient use of water for agriculture in downstream rivers are primarily focused on improving irrigation techniques, changing plant varieties and structure, or improving small water storage models for crops with high drought to lerance. There is no optimal solution of rainwater storage and water supply for the dry season.

Therefore, the topic titled "Study on building the optimal solution of irrigation water storage to minimize the effect of drought on agricultural production in downstream Ca River - Case study in Le Xuan Dao irrigation system" is of scientific and practical significance.

2. Objectives of the thesis

- Determine the water supply needs and capacity of the irrigation system in the dry season and propose appropriate solutions for water storage in service of agricultural production.
- Apply the optimal solution to develop a real-time operation plan for the proposed solution, to ensure sufficient water supply during dry season, and to save costs in operating the system.

3. Scope and subjects of research

The thesis focuses on water storage solutions and develops optimal operating algorithms for water regulation in real time in nine communes of Le Xuan Dao canal. The southern Nghe An irrigation system is one of the worst drought areas.

4. Research methods and approach

Method of survey and data collection; Inheritance method; Statistical (probability) method; Mathematical modeling method; Optimization method in system operation management

5. Scientific and practical significance of research

Scientific significance: Develop the methodology and optimal algorithms to operate the irrigation system in dry season by water storage. In the study of system operation, the optimal search algorithm was set up in the Matlab programming language. This algorithm obtains ***the non-dominated sorting genetic algorithm II (NSGA-II)***(Deb 2000) as the basis.

Practical significance: The thesis proposes the optimal solution and plan for the irrigation system for dry season in 9 communes in the southeast of Hung Nguyen district, Nghe An province. This solution can be applied to other areas with similar natural conditions.

6. New contributions of the thesis

1. The optimal solution has been developed to support decision making on irrigation water storage and to minimize the impact of drought on agricultural production.
2. The optimal solution and plan are proposed for irrigation system Le Xuan Dao in dry season.

The results of the thesis can be referenced and applied to similar systems.

7. Structure of the thesis

The thesis is presented in three main chapters as follows:

Chapter 1. Overview

Chapter 2. Methodology and Research Tools

Chapter 3. Research results

CHAPTER I. OVERVIEW

1.1 Droughts and impacts of drought on agriculture

1.1.1 Droughts and causes

Drought is a widespread phenomenon in most geographic regions of the world, which are complex and affecting many people. According to the European Drought Center, drought is a phenomenon where the amount of water available in the wild is below the average for a long time. Droughts affect all components of the hydrological cycle. The reduction of precipitation leads to a decrease in soil moisture, additional water and groundwater reserves, and consequently, reducing the flow or drying up rivers and streams.

Researchers at the National Drought Mitigation Center of the University of Lebrasca-Licolc (USA) have classified drought into four basic types: 1) meteorological or climatological, 2) agricultural, 3) hydrological, and 4) socioeconomic.

Droughts can be categorized in a number of ways.Basically, however, the classification isbased on multi-year statistics on precipitation in drought years.

The basic factors to classify droughts include:

- Rainfall (month, season).
- Ground water level.
- Water level/capacity of reservoirs.
- Water level and flow in rivers and streams.

1.1.2 Some effects of drought on agricultural production in the world

In southern Europe, the results suggest that high temperatures and droughts may worsen in areas where surface water is scarce and areas with heat waves. Africa is one of the typical areas where droughts cause widespread poverty for people in the continent.In the United States, during the drought years, economic damage in this country is very serious. Studies have estimated that the annual damage caused by drought is about6-8 billion dollars per year. In China, in 1941, drought caused nearly three million deaths. In India, from 1769 to 1770, drought caused 5 million deaths from hunger and disease. In Japan, in 1994, a long wave of high temperatures caused a severe drought in more than one-third of the country's territory. In 1982-1983, Australia suffered its worst drought in the 20thcentury. In 1997, 1998, due to the influence of the El Niño phenomenon, countries in Southeast Asia had almost no rain, and high air temperatures were the main cause of forest fires in many places, typically Indonesia and Malaysia.

1.1.3 Impacts of drought on agricultural production in Vietnam

In Vietnam, drought occurs in both the areas with many rains and the ones with less rains, and in both the dry season and the rainy season. Droughts are also very different in ecological regions. The delta and midland areas often experience drought in the winter-spring crop; drought rarely occurs in the summer-autumn crop. In Central Vietnam, from Nghe An to Binh Dinh, drought often occurs in the summer-autumn crop.In the South Central region, drought often occurs in the winter-spring crop. In the south-western part, drought often occurs at the end of the winter-spring crop. Central Highlands often encounter drought in winter-spring crop and early summer-autumn crop.

1.1.4 Drought situation in the study area

In recent years, droughts in Hung Nguyen district, particularly in Hung Chau, Hung Loi, Hung Yen, Hung Phuc and Hung My communes have been severe. Dry season rainfall continues to decline, the rainfall in the next year is lower than that in the previous year. Along with the impact of the Lao wind, the drought in these areas is more severe. In recent years, drought has been more frequent and severe, such as droughts in 1983, 1987, 1988, 1990, 1992, 1993, 1998, 2003, 2004 and 2010 and extremely severe droughts in 1993, 1998 and 2010.

1.2 Research and solutions against drought

1.2.1 World

Drought research, forecasting and estimation activities are currently being implemented in almost every country in the world. However, due to the complexity of the nature of the phenomenon, there is no uniform method in the study of drought.

Many governments around the world have also made significant expenditures for water supply and drought mitigation projects, such as the At-soan dam project on the Nine River in Egypt. China has established the world's oldest disaster warning association with the United States. Israel and India have also made great strides in the study of drought-resistant, water-saving irrigation technologies.

The combination of agro-forestry measures and techniques of water storage in water-shortage areas has been studied and applied by many countries such as India, Sri Lanka, Egypt, Kenya, etc.

1.2.2 Vietnam

In Vietnam, managers and scientists have focused heavily on the study of drought prevention solutions. The following basic solutions are focused on:

- Constructing the integrated exploitation works to regulate the flows in the dry and rainy seasons.
- Raising the level of assurance of irrigation and water supply works.
- Managing and increasing the coverage of protection forests, upstream forests.
- Controlling the discharge of toxic wastes into water sources.
- Operating effectively irrigation systems.
- Improving the quality of hydro-meteorological forecasting, especially the long-term forecast.
- Raising community awareness and participation.
- Managing the water demand.

1.3 Optimization problem

1.3.1Overview of optimization problem

The goal of the optimization problem is represented by the function f (x) $\rightarrow$ min (max) where x is a variable or vector of variable x = (x1, x2, ...,xn)

The variable x or the vector of variable x = (x1, x2, ...,xn) is often required to satisfy certain conditions. The set of conditions of variables is called binding conditions and is represented by domain D (binding domain).

General form of optimization problem:

Minimizing/Maximizing a target function: f (x) $\rightarrow$ min (max) (1)

Satisfying binding conditions x $\in$ D (2)

Request: Find x to satisfy (2) and to minimize/maximize the objective function (1)

x (a set of specific values of (x1, x2, ..., xn)); if satisfied, conditions (1) & (2) are optimal options.

If x satisfies only condition (2), x is an acceptable option.

In 1988, Edgar and Himmelblau proposed the following steps to develop and solve the system optimization problem:

Step 1: Analyze the essence of the problem so that specific characteristics can be clearly seen and the optimal system can be identified.

Step 2: Determine the optimum criteria, set the objective function from the specified optimal variables and the corresponding coefficients.

Step 3: Develop a system of simulated mathematical relations, link the optimal variables, the input data, and the corresponding coefficients.

Step 4: In cases where the scope of the problem is too large, (i) divide it into smaller parts for easier simulation, (ii) simplify the objective function or simulation.

Step 5: Apply the appropriate technique.

Step 6: Examine the results, analyze the sensitivity of the model by changing the coefficients as well as assumptions.

1.3.2 Optimization techniques

Currently, there are two approaches to solving the optimization problem, namely:

- Implicit Stochastic Optimization (IOS).
- Optimal Stochastic Optimization (ESO).

Optimal techniques are often used:

- ❖ Linear Programming
- ❖ Nonlinear Programming
- ❖ Dynamic Programming
- ❖ Meta heuristic

Introduction to NSGA II

Optimal Search Technology: ***Non-dominated sorting genetic algorithm II (NSGA-II)*** is an improvement of the None Dominated Sorting Genetic Algorithm.

- **Application of NSGA II in practice**

With the outstanding advantages compared to other algorithms, in practice, the world has adopted NSGA II pretty much in the field of water resources. There are some case studies. In 2006, two scientists, Taesoon Kim and Jun-HaengHeo, used NSGA II for optimizing the multi-reservoir system in the Han River basin, South Korea. In 2006, Md. Atiquzzaman, Shie-YuiLiong, M.ASCE, and Xinying Yu used NSGA II to studyan alternative solution for the water distribution network. In 2016, FeifeiZheng, Aaron C. Zecchin,Holger R. Maier, and Angus R. Simpson studied and compared the search quality and convergence of three algorithms including NSGA II, SAMOD and Borg applied to 6 water distribution systems.

1.4 Overview of optimal application of irrigation systems in the world

In recent years, scientists around the world have focused on the best research in the water sector. Optimization models, including dynamic optimization models for water systems of countries, especially systems of developing countries such as India, China, Arabia, Bangladesh, Brazil, etc.,are used for most of the water resources related fields such as irrigation, power generation, aquaculture, domestic water supply, and regulation and distribution of water demand among these sectors in the same basin. It can be said that the research application of both static and dynamic optimization techniques are widely used in the field of water management technology in the world.

1.5 Overview of optimal application of irrigation systems in Vietnam

In Vietnam, the dispute over water resources is increasingly acute. Competition between water sources for electricity generation and other water consumption needs, especially for agricultural production in the lower part of some large river basins such as Red River, Ma River, Ca River, Vu Gia River - Thu Bon, etc. has become fierce.

The application of optimization to the allocation of water resources has been implemented in many river basins in Vietnam since 2000 as can be seen in Dong Nai river basin, Red River - Thai Binh basin, La Buong river basin, Be river basin, Srepok river basin, and Ba river basin.

Conclusion of Chapter 1

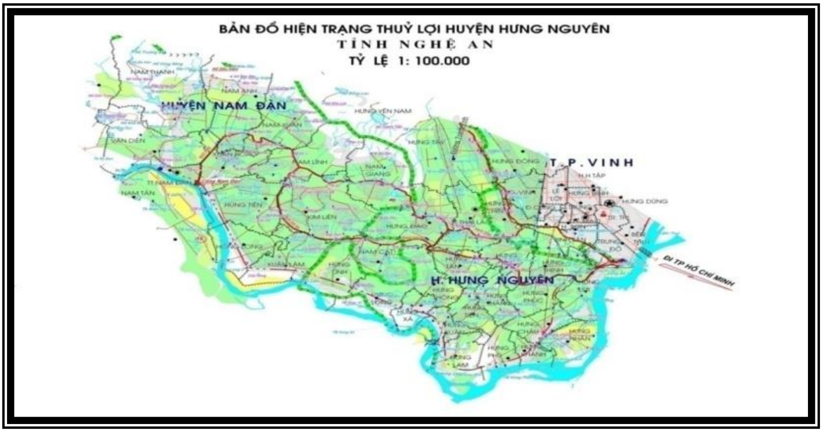
At present, in Vietnam, most of these studies are limited to research on storage solutions forpreserving enough water in the dry season. There is no optimal water storage solution to take advantage of the rainy season water without waste. The thesis focuses on the optimal water storage solution which regulates water in real time on the system to ensure effective water storage for agriculture in the period of lack of water.

CHAPTER II. METHODOLOGY AND RESEARCH TOOLS

2.1 Introduction to the study area

2.1.1 Profile of the study area

Le Xuan Dao canal is located in the lower section of Ca river, including nine communes in the southeast of Hung Nguyen district, belonging to the southern system of Nghe An. The study area is in the range 18^0 35 minutes to 18^0 47 minutes latitude north and 105^0 35 minutes to 105^0 40 minutes east longitude.



Sources: DARD Nghe An

Figure 1: Study area map

2.1.2 Status of agricultural development in the study area

Total area of 9 communes is 4,637.6 ha, of which agricultural land areais 2,475.41 ha, forest land area is 31.47 ha, specialized land area is 752.93 ha, residential land area is 162.46 ha, and unused land area is 1,197.28 ha.

2.1.3 Status and effects of drought

In the last 15 years, droughts have beenmore frequent and severe, such as droughts in 1983, 1987, 1988, 1990, 1992, 1993, 1998, 2003, 2004 and 2010 and extremely severe droughts in 1993, 1998 and 2010.

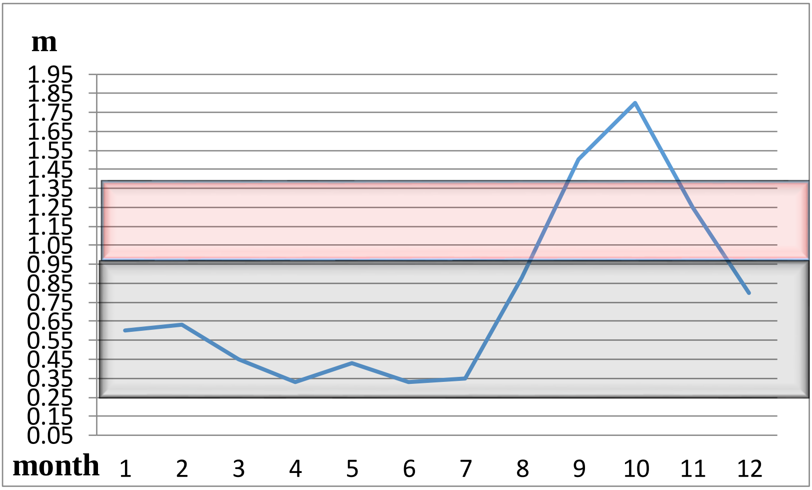


Figure 2: Monthly average water level of the upper section of Nam Dan Sluice Gate (2010)

2.2 Research content and approach

The goal is to propose a wet season irrigation solution for use in the dry season and optimize the real-time regulation of the system as outlined above. The author focuses on the following main contents:

- Content 1: Assessment of the current status of the system
- Content 2: Determination of water demand.
- Content 3: Calculation of water shortage in dry season
- Content 4: Proposal of water storage solutions

- Content 5: The optimal solution for real-time water regulation on the system

2.3 Research methods and tools

2.3.1 Calculation of water demand

There are now many methods for calculating evapotranspiration for plants. FAO has proposed four methods depending on the climatic conditions and the actual situation of the actual measurement documents to be applied in different regions. According to experts, the Penman Method usually produces the best results. Based on that fact, the author selects the Penman method to calculate evaporation. The calculation of water demand is based on FAO’s CROPWAT program.

2.3.2 Hydraulic calculation

In this study, the author uses MIKE11 model to calculate water level, flood flow, minimum stream flow for river networks in the area.

2.3.4 Optimal operating problem on the system

In order to ensure the water supply in the dry season for the study area, the use of submersible canals available in the area for rainwater storage used in dry season is an effective solution. In practice, however, the operator encounters a conflict between the flooding level and the minimum stream flowduring the operation of water stored in the canals.

The climate in the area is unusual and difficult to predict. If the flooding amount is small and the flood season ends prematurely while water volumein canals is small at the end of the flood season, there will be insufficient water in the dry season. If the flooding amount is large and the flood season ends late while water volume in canals is large water, the loss in the system is very serious.

The goal of the problem is to find a real-time operation function to optimize and harmonize both of these goals.

To calculate the amount of water stored, the author develops the following function for calculation of the amount of water taken into the system**:**

$$[\boldsymbol{uI_t}] = \mathbf{f}(\boldsymbol{s_t}, \boldsymbol{SYS}, \textbf{ENSO index}, \textbf{WLNĐ}_{\mathbf{t}}, \mathbf{t}); \qquad (2.1)$$

Where, uI_t is calculated as follows:

$$\boldsymbol{uI_t} = \boldsymbol{uI_t}\mathbf{min} + (\boldsymbol{uI_t}\mathbf{max} - \boldsymbol{uI_t}\mathbf{min})\ \mathbf{x_1}; \qquad (2.2)$$

Hyperbolic Function: $\mathbf{Tanh\ (x)} = \frac{e^x - e^{-x}}{e^x + e^{-x}} = \mathbf{x_1}$ (2.3)

$$\mathbf{x = s_t.w_{11} + (\textbf{ENSO index}).w_{12} + \textbf{WLNĐ}_t.w_{13} + t.w_{14} + d_1} \qquad (2.4)$$

Where:

uI_t: Value of the variable to be taken into the system at time t;

x: Intermediate variable

W_{ij}: Weight of the input layer; $\mathbf{0<w_{ij}<1}$

Y: Input of network activation function

d: Deviation of hidden layer input

t: Time of calculation

$WLNĐ_t$::Nam Dan water level at time t;

s_t : Volume on the canal at time t;

SYS: Physical characteristics of the system (pumping capacity, canal capacity);

ENSO index: Data about the ENSO index provided by IRI.

The process of finding the optimal solution is to find the set of parameters $W_{ij}$and d_i.

Thus, the optimization framework will be responsible for searching for the operation function, based on the optimization problem set up as follows:

2.3.4.1 Development of a specific objective function for the study area

Goal 1: Shortage of water for crops in the study area should be minimal

$$\mathbf{Min}\sum_{i=1}^{N}(W_{shortage_i}) \tag{2.5}$$

if Wd>Ir then $W_{shortage_i}$ **= Wd_i – Ir_i, else** $W_{shortage_i}$ **= 0**

Where:

$W_{shortage_i}$: Water shortage

Wd_i: Water demand for plants

Ir_i: Irrigation water

Goal 2: The volume of water should be minimum

$$\mathbf{Min} \sum \mathbf{W_{irrigation}} \tag{2.6}$$

$$\mathbf{W_{irrigation_t}} = \mathbf{f}(s_t, \mathbf{R}, \mathbf{T_{req}}, \mathbf{SYS}) + uI_{t-1} \quad \text{if } uI_t < 0 \tag{2.7}$$

$$\textbf{Else} \quad \mathbf{W_{irrigation_t}} = \mathbf{f}(s_t, \mathbf{R}, \mathbf{T_{req}}, \mathbf{SYS})$$

$\mathbf{T_{req}}$: Threshold

2.3.4.2 Constraints

$$I_t + R_t + S_t = \mathbf{IR} + W_{lost} + W_{\mathbf{irrigation}} + E_t + S_{t+1} \tag{2.8}$$

I_t : Amount of intake water, depending on U_I

$uI_{min} \le uI \le uI_{max}$;

uI_{min} depends on the water level in the canal and the pumpingcapacity of the system

uI_{max} depends on Nam Dan sluicegate water level and the intakecapacity of the system

s_t : Volume on the canalat the time of calculation t;

s_{t+1} : Volume on the canalat time t + 1;

R_t : Rainfallat the time of calculation;

IR = uIR x S; (2.9)

S: Planting area;

E_t : Evaporation at the time of calculation;

W_{lost} : Water loss at the time of calculation;

$W_{lost} = s_t$ x K_{th}; (2.10)

K_{th}: Permeability coefficient;

$W_{irrigation}$: Quantity of water;

$W_{irrigation}$= f(s_t , R) (2.11)

Other constraints such as pumping capacity and other physical characteristics of the system have been addressed in the decision-making function.

2.3.4.3 Framework for optimal solution and NSGA II

NSGA stands for ***Nondominated Sorting Genetic Algorithm II***.

Variables:

P_t: Parent population;

Q: Sub-population that is made from individuals P_t;

F_j: Variable that contains nondominatedsolution, with j=1, …, R;

N: Number of individuals in the population P_t;

Algorithm:

Step 1: Randomly generate the parent population $P_0$with$|P_0|$= N; Assign t = 0;

Step 2: Apply the crossover and mutation operator to the individuals in population P0 for population $Q_0$with $|Q_0|$= N;

Step 3: If the stop condition is satisfied, stop and export individuals in the population Pt.

Step 4: Set $R_t = P_t \cup Q_t$

Step 5: Use NSGA to identify non-dominant variables F_1, F_2, …,F_k

Step 6: For each i = 1, ..., k, perform the following steps:

- Calculate the distances of the solutions in F_i
- Create population P_{t+1}as follows:

If $| P_{t+1} + F_i | \leq N$, then set $P_{t+1} = P_t \cup F_i$

If $| P_{t+1} + F_i | > N$, then addN - P_{t+1}solutionswhere other individuals converge the least from population F_i inP_{t+1}

Step 7: Use the binary selector operator based on the accumulation distance on the x-solution to select the father species from the Pt + 1 population. Apply the diagonalization and mutation for population Pt + 1 to create population Qt + 1 with Qt + 1 | = N.

Step 8: Assign t. Go back to step 3

Conclusion of Chapter 2

The methods used in the thesis are based on a rigorous scientific basis. For applying these methods, the author has used a variety of advanced tools such as Cropwat, Mike 11, Mike Basin and especially NSGA II. The result of a multi-objective optimization function shows that Pareto is a set of non-dominant optimization solutions, each of which is an optimal operating solution for the system.

Chapter 2 describes in detail the techniques used in the study, provides an optimal framework and sequence of implementation, and clearly explains the algorithm that will be used.

The application of optimum techniques in the construction of operational solutions for an irrigation system is new and ***NSGA II*** is not used to calculate any irrigation systems in Vietnam.

CHAPTER III. RESEARCH RESULTS

3.1 Water storage solution for agricultural production in the dry season

3.1.1 Results of calculating water demand

3.1.1.1 Water demand for cultivation

Based on CROPWAT.7, the water demand for crops with frequency of 75% and 85% is calculated as shown in Table 3.1.

Table 3.2. Water demand for cultivation

Unit: $10^6 m^3$

Zone	1	2	3	4	5	6	7	8	9	10	11	12	Total
Frequency 75%													
Zone VII	23.18	18.34	28.16	45.99	34.12	37.08	41.59	12.26	3.14	0.00	0.49	29.72	274.07
Frequency 85%													
Zone VII	22.94	20.52	30.25	45.24	34.85	41.22	44.70	10.76	5.20	0.01	0.65	31.04	287.37

3.1.1.2 Water demand for animal husbandry

Based on the water supply norms for animal husbandry and the number of livestock herds, the demand for water for livestock production is calculated based on the months in the study area as shown in Table 3.2.

Table 3.2. Water demand for animal husbandry

Unit: $10^6 m^3$

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
Demand	0.40	0.36	0.40	0.39	0.40	0.39	0.40	0.40	0.39	0.40	0.39	0.40	4.71

3.1.1.3Water demand for aquaculture

Based on the aquaculture area of the study area (4282ha, of which freshwater aquaculture is 3,942ha and brackish water is 340ha) and water supply norms, the result of calculation of water demand for aquaculture is shown in Table 3.3.

Table3.3. Water demand for aquaculture

Unit: $10^6 m^3$

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
Demand	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	4.250

As a result of calculating the water demand for water users, the total water demand for the whole country with the frequency of 75% is 525.46 million cubic meters and the total water demand with the frequency of 85% is 547.62 million cubic meters.

3.1.1.4 Water demand for living

Based on the daily water supply norms, the water demand in the study area is calculated as shown in Table 3.4:

Table3.4. Water demand for living

Unit: $10^6 m^3$

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Demand	3.20	2.89	3.20	3.10	3.20	3.10	3.20	3.20	3.10	3.20	3.10	3.20	37.67

Thus, the total water demand for living in the whole region is about 37.67 million m^3.

3.1.2 Result of water shortage/water balance calculation

For the Le Xuan Dao Canal, with a frequency of 75%, the shortage of water often occurs from December to July next year, focusing on January, March, April, July, from 5 to 18%. The biggest shortfall is in July with a deficit of 0.83 million cubic meters.The least shortfall is in December with a deficit of 0.35 million cubic meters. In the whole year, the total water shortage is 2.31 million cubic meters. With the frequency of 85%, the shortage of water usually occurs from December to July next year, focusing on December, January, February, March, April and July, from6 to 20%. The biggest shortfall is in April with a deficit of 1.51 million cubic meters. The least shortfall is in Januarywith a deficit of 0.42 million cubic meters.In the whole year, the total water shortage is 7.58 million cubic meters. For nine communes in the study area,the total water shortage is 1.65 million cubic meters.

3.1.3 Proposal of water storage for dry season

In the past, when these canals were built, dredged land was used to fill the banks in order to save costs. The system has five main canals and the author proposes to expand the canals as shown in Table 3.5.

Table 3.5.Recommended canal size

Canal name	***Suggested size (m)***			***Slope(m)***	***Storage capability (m^3)***
	L	B	H		
Canal 12/9 (section 1)	*2,500*	*8.0*	*4.0*	1.5	***124,294***
Canal 12/9 (section 2)	*1,800*	*5.0*	*4.0*	1.5	***79,558***
Le Xuan Dao	*3,500*	*6.0*	*4.0*	1.5	***124,385***
HanhpHuc	*1,800*	*6.0*	*4.0*	1.5	***63,969***
TienThang	*18,300*	*22.0*	*3.5*	1.5	***1,255,380***
Hung Nghia		*22.0*	*3.5*	1.5	
Total					***1,647,586***

3.2 Development of a real-time operation function for the nine communes of Le Xuan Dao canal to store water for the study area

The calculation of operation for the system depends on the amount of incoming water, rain and capacity of the whole system, especially the Le Xuan Dao canal where the Hung Chau pump station is located. The calculation steps are as follows:

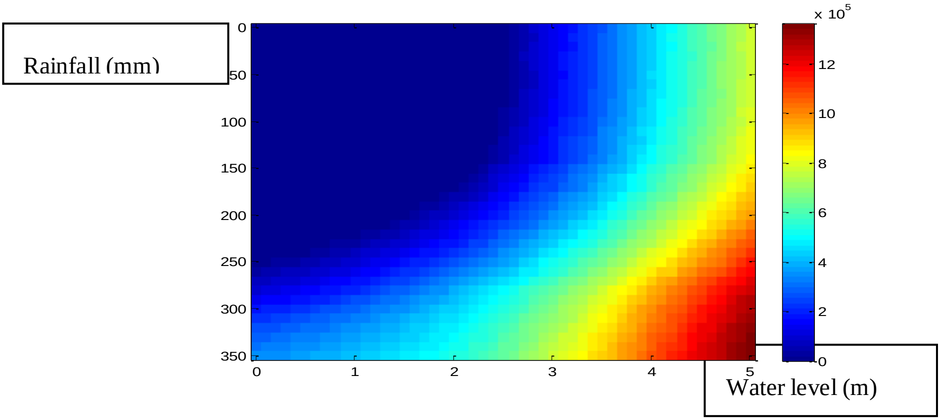
3.2.1 Irrigation model

To build the irrigation model for the system, if using Mike 11 directly, the calculation process will take a lot of time. Thus, the author proposes that the solution to construct a matrix which is the independent result from Mike 11. Through two steps:

Step 1: Setting up the Mike 11 drainage model for the system:

Step 2: Application of model Mike 11 to build the irrigation matrix for the system

A total of 1,836 scenarios have been produced, resulting in two results about (i) total daily drainage correlations based on daily rainfall and water levels in the canal at the beginning of each day; (ii) relation of water levels in the canal at the end of each day, daily rainfall, and water levels in the canal at the beginning of each day.



Matrix of relation of rainfall, water level in the canal, and amount of water to be drained

The chart illustrates some typical results of the rain relation table, water level on Le Xuan Dao canal, and amount of water to be drained

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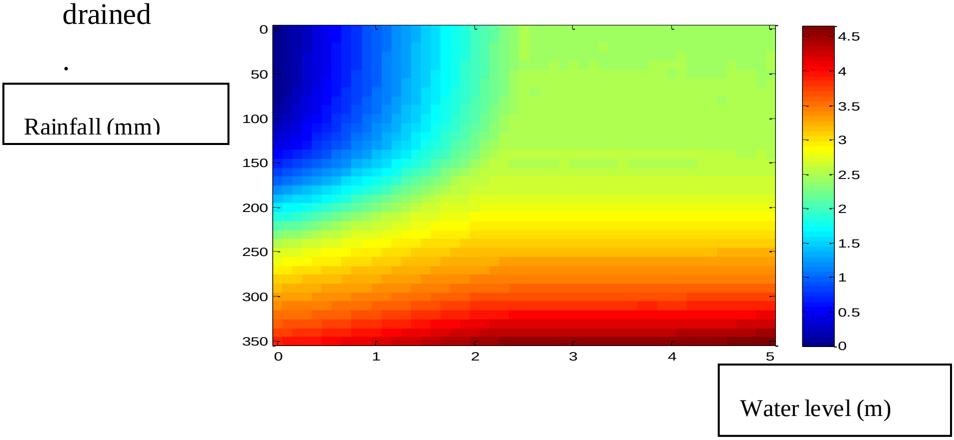


Matrix of relation of rain, water level in the canal, and water level in the canal at the end of the day

The matrix of relation of rain, water level in the canal, and water level in the canal at the end of the day is a table with each rainfall and the water level in the canal at the end of the day. It will show the water level at the end of the day. This result will be the input for calculating the next day's drainageflow.

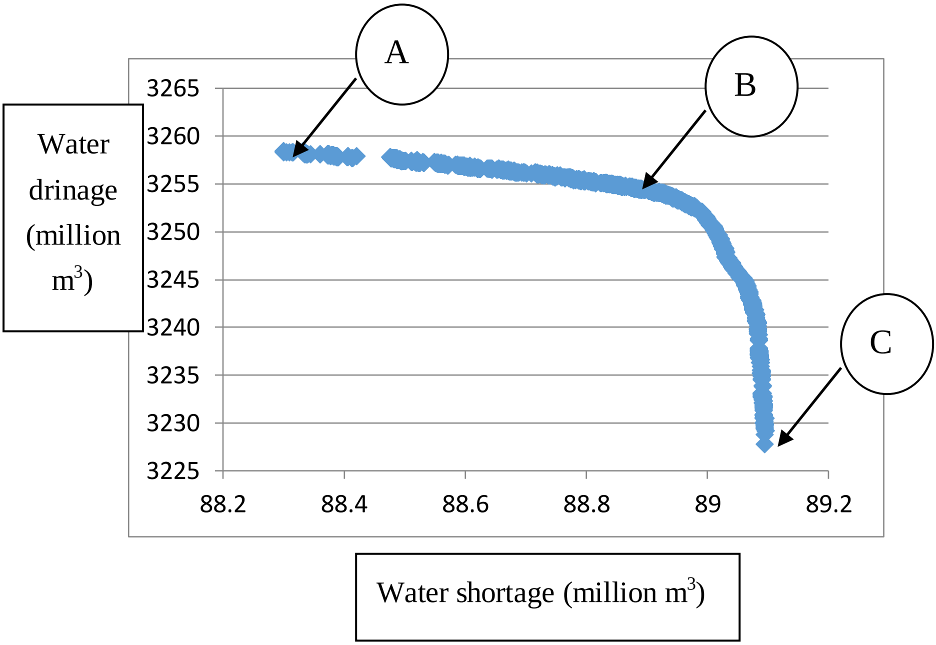
3.2.2 Calculation of the input data for models

After applying the formulas, Matlab is used for modeling, with a time series of 50 years (18,250 days), results in total discharge, actual volume of the system, incoming flow, rainfall flow and total surface evaporation on the canal.

3.2.3 Pareto face and operation solution

The entire solution framework was written in the Matlab language calculated on a 50-year time series, by date, totaling 18,250 steps. The problem is calculated optimally over 200 generations; in every one generation, the number of individuals in the population is 5,000. Thus, we have 5,000 x 200 (= 1,000,000) evaluations. We can understand 5000 individuals are 5000 operation solutions. The initially proposed 5000 solutionsare called the parent population, the following 5000 solutions are called subpopulations.

In the process of running the computational model using NSGA II to the near-200 generations, the pareto side has no further development and is almost stopped so that NCS stops the running process at the 200^{th} run (200^{th} generation). After calculation, the solution is Pareto.



3.2.4 Application calculations for typical years

Author selection 2014 is the year to calculate the test. In 2014, all types of drought and floods occured the study area. Compared to the three typical representatives A, B and C of the

pareto optimization side for testing for 2014, better results are shown.

Conclusion of Chapter 3

The irrigation and drainage problem in the system is a complex system of complicated nonlinear equations that are not easy to deal with conventional optimization algorithms. Choosing an algorithm that is part of a multi-objective evolution class such as NSGA II ensures that a closer approximation to a global solution is better than the robust nonlinear algorithm that normally guarantees local solutions. This algorithm also has the advantage of easily incorporating hydrothermal models such as Mike 11.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Based on these tools, the ISO approach (random optimization) is used. But instead of defining functions through correlated calculations as in previous studies, the author uses the direct search of the operating function through the parameterization of the operation function from the beginning. After more than 5 days of calculations, the algorithm succeeded in finding the pareto consisting of the optimal solutions not in the target function space of the total water drainage and the amount of water shortage. These optimal solutionswere tested for 2014 and demonstrated its remarkable ability to help reduce the amount of water drainage as well as reduce the amount of water shortage. Thus, with this pareto, the stakeholders (system board) will be able to select a suitable operation solution and assign it to the operator in practice.

Recommendations

Due to the complexity of the study and calculation process, the data collected and processed for the study only meet requirements at a certain level.

Computational technique is advanced that requires support devices with a strong enough configuration to handle. In the study, the author used a computer chip Xeon E5 V2567, 32 cores, RAM 128 G, CACHE 32 Mb, memory 20 TB that is a specialized machine with high configuration. Ittook more than 5 days for results.

Due to these difficulties, further research is needed to improve the computational technique in order to speed up the calculation process in order to achieve higher efficiency.

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