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# Optimization design of irrigation water management to reduce field failure risk

A K Hidayat<sup>1</sup>, I N Norken<sup>2</sup>, M I Yekti<sup>3</sup>, P Irawan<sup>4</sup> and A S Kosnayani<sup>5</sup>

<sup>1,4</sup>Civil Engineering Department, Faculty of Engineering, Siliwangi University,  
Jl. Siliwangi No. 24, Tasikmalaya, West Java, Indonesia

<sup>2,3</sup>Civil Engineering Department, Faculty of Engineering, Udayana University  
Jl.P.B. Sudirman, Denpasar, Kota Denpasar, Bali, Indonesia

<sup>5</sup>Nutrition Department, Faculty of Health Science, Siliwangi University  
Jl. Siliwangi No. 24, Tasikmalaya, West Java, Indonesia

Email: asepkurnia@unsil.ac.id

**Abstract.** The existing condition of the irrigation area after construction or the irrigation area in operation needs to be evaluated because in the planning of water availability and irrigation water needs many parameters-parameters which is the result of the analysis approach or indeed the data - the data that then changed. The changing conditions of the data will cause many impacts. The risk of field failure is one of impact if water availability is less than the initial estimate. This paper reports the analysis of the availability of water and irrigation water requirements is dynamic, in this study the availability of water is analyzed with 80% reliability. Irrigation water demand is based on regulation of planting schedule and reduction of field area with the intention of reducing the risk of greater field failure. The results obtained are alternative field area of optimum irrigation, regulation of planting schedule and operation of floodgates in the taking or building structure for the review. Field area and Regulation of planting schedule are analyzed by simulation. The mathematical model that will be produced is the optimum model of irrigation water management and mathematical model of field failure risk. This study can be an evaluation model especially for irrigated areas in dry field areas.

## 1. Introduction

Indonesia includes a country with more than one million hectares of irrigated field, measuring 6.8 million hectares [1]. Field planted in Indonesia of 18 million hectares, and irrigated areas covering 6.8 million hectares or 38%. In 2013 the width of rice fields in Indonesia covering an area of 8,112,103 hectares consists of irrigated rice fields of 4,819,525 hectares and irrigated rice fields of 3,292,578 hectares [2]. West Java Province has a rice planting area of 936,529 hectares and paddy rice harvested area for a year 1,979,799 hectares [3]. The decrease of paddy rice harvest area and paddy field production of the north coast of west java is 77,00 ha/year and 926,10 ton/year [4].

The irrigation problem is technically one of them is the water balance problem. Water equilibrium in irrigation is a condition where the availability of irrigation water is equal to the availability of water. Conditions in the field are 3 (three) possibilities: (1) Condition of water availability is greater than irrigation water demand, (2) condition of water availability equal to irrigation water demand and (3) condition of water availability less than irrigation water requirement. Field failure or crop failure in irrigation areas is more often caused by the condition (3) where there will be drought. Conditions (1)



and (2) can sometimes lead to field failure or crop failures when drainage management is not working so the inundation causes the crops to break down and under conditions (2) field failures occur when water regulation is not working so water users scramble.

Research conducted on Cimulu Irrigation Area of 1546.20 hectares located in Tasikmalaya city. The extensive review of irrigation areas is relatively small for Integrated Water Management (IWM) to be more easily managed. Following the steps of the Integrated Water Management (IWM) approach in Indonesia, the EU, Brazil has shifted from a top-down approach to participatory water management involving various segments of society, that means participation and involvement of community segment will be easier if the scope is getting smaller [5]. Irrigation farm field simulations generally do not have a key interaction between the water requirements of plants and the water supply from irrigation systems [6]. Location Cimulu Weir located in the Village Tawangsari Tawang District Tasikmalaya City is located on 7° 19' 14.6" latitude and 108° 13' 17.4" longitude. Cimulu Weir lies on the Ciloseh river which is in the management of PSDA Center of Citanduy River Region. Cimulu Wei irrigates Cimulu Irrigation Area which is part of Citanduy Upstream Service Unit of PSDA Region Citanduy River Region. Irrigation Area Cimulu with irrigation area 1546.20 hectares consisting of 3 (Three) Working Areas Observers are (1) Working Area Observers Cimulu with 1008 hectares of rice fields, (2) Work Area Observers Dalemsuba with irrigated area 316.20 hectares (3) Cihanjang Observer Working Area with 222 hectares of the rice field area.

The real condition after the construction of the irrigation area needs to be evaluated, because in the planning of water availability and irrigation water demand there are many parameters which are the result of empirical analysis and approach. The condition of water availability in planning is also an empirical and statistical approach so that there is a possibility of real water availability condition less than irrigation water requirement. Failed field can occur either because of the availability of water is smaller and the availability of water is greater than the need for irrigation water. Therefore, it is necessary to re-analyze the post-structural irrigation area by arranging the operation of water gates in the building for and intake, the arrangement of planting schedule, and regulation of existing irrigation field. Research after completion of the structure becomes important because the condition of water availability is smaller than the needs of irrigation water will lead to disputes and seizure of water irrigation water user level so that the need for re-regulation. This model will produce an operating model of irrigation watergate and how much optimum field can be supplied. Mathematical model that will be produced is a mathematical model of optimization of irrigation water management and mathematical model of field failure risk.

Irrigation management research has been done using a technical approach [7]. These approaches are (1) research of irrigation water needs with observations in the field of evapotranspiration, percolation, evaporation, water discharge, soil physical properties. (2) research in the form of soil testing to find out soil texture and permeability coefficient by comparing the results in laboratory and observation of inflow-outflow discharge, percolation, evaporation and transpiration on the rice field. (3) research of water needs on the critical field through the bamboo system to know the physical condition and texture of soil in water absorption. (4) the provision of irrigation water supply system on the isolated field to determine the irrigation water supply system in the dry season by giving minimal administration and plant growth with the evaporation process system from the dew, and it turns out that some of these studies are still not optimal in finding the proper irrigation management. Research on the possibility of field failure from the existing water balance in the existing irrigation area, ie the post-structure or irrigation areas that are already operating or running which due to many factors, will certainly undergo many changes in the operation so that it is no longer in accordance with the time of planning, yet much researched.

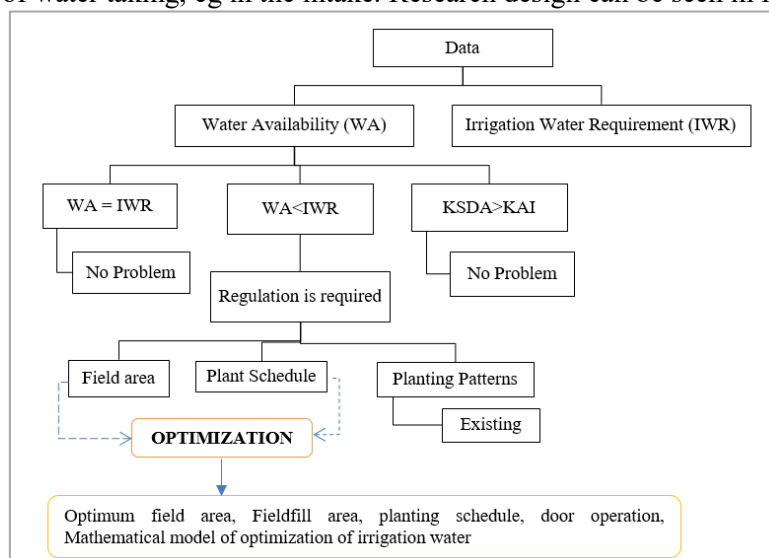
This study offers a Dynamic system for the optimization of irrigation water management based on field failure risk, this system is an empirical system that is expected to predict the risk of field failure from the existing irrigation area, resulting in door operation from the intake door at the weir location and several buildings regulation. This system will produce the optimum area that may be irrigated with available water availability and if the irrigation system is forced to operate in accordance with available

field or even increase the area of irrigation then it is predicted to risk field failure or crop failure. Thus this system can be used to reduce the risk of irrigation field failure. This system can be applied to irrigated areas with limited water availability or where water availability is less than irrigation water needs. The regulation is based on fixed parameters and the parameters change. The required parameters are planting pattern, type of rice variety, planting schedule, effective rainfall, water availability at door and irrigated area.

## 2. Methods

### 2.1. Research design

This review is a draft to review the post-construction irrigation area. The assessment can be applied to any existing irrigation areas that suffer from water shortages. Implementation in irrigation areas can be done at any point of water taking, eg in the intake. Research design can be seen in figure 1.



**Figure 1.** Research design.

### 2.2. Research stages

The stages conducted in research as follows:

- Preparation
  - Preparation of data for analysis of irrigation water needs and water availability
- Analysis
  - a. analysis of water availability
  - b. analysis of irrigation water needs
- Factor analysis “k”
  - There are 3 possibilities  $k = 1$ ,  $k < 1$ ,  $k > 1$ , when  $k = 1$  and  $k > 1$  no problem
- When  $k < 1$ 
  - Regulation of planting schedule and/or reduction of irrigation area is applied
- Obtain mathematical model
  - a. obtained optimum irrigation area and planting schedule
  - b. operation of water gates and field area at risk of failure
  - c. mathematical model of optimization of irrigation water management
  - d. mathematical model of field failure risk

### 2.3. Data analysis

The data source is field data of Cimulu Irrigation Area located in Tawangsari Village Tawang District Tasikmalaya District. Climate data and climate data obtained from BPWS Citanduy. Existing data on cropping pattern and planting schedule are also obtained from the community, government apparatus, BPWS Citanduy, Citiguy Upstream SUP area of PSDA of Citanduy River Region in Tasikmalaya and Tasikmalaya. The data are collected from reports written in report forms consisting of 10 types of blanks. In the data analysis is limited some things as follows:

- a. The existing irrigation water discharge is measured at the weir intake for the irrigated area under consideration and is considered to be repeated with the same pattern
- b. The availability of river water discharge in the analysis for 80% dependent discharge
- c. Analysis of irrigation water needs based on the semi-monthly planting period, so that in one year for three growing seasons there are 24 periods
- d. Effective rainfall is assumed to be 70% and dependent rainfall 80%
- e. Comparison of discharge for Irrigation Area in the first building is assumed to be proportional to the area of each irrigation area.
- f. Variables in this study consist of (a) variables for the analysis of water availability are (1) the measurement of discharge in the intake, (2) the measurement of the discharge in the building for, (b) the variables for irrigation water requirements are (1), (2) effective rainfall, (3) irrigation area, (4) temperature.

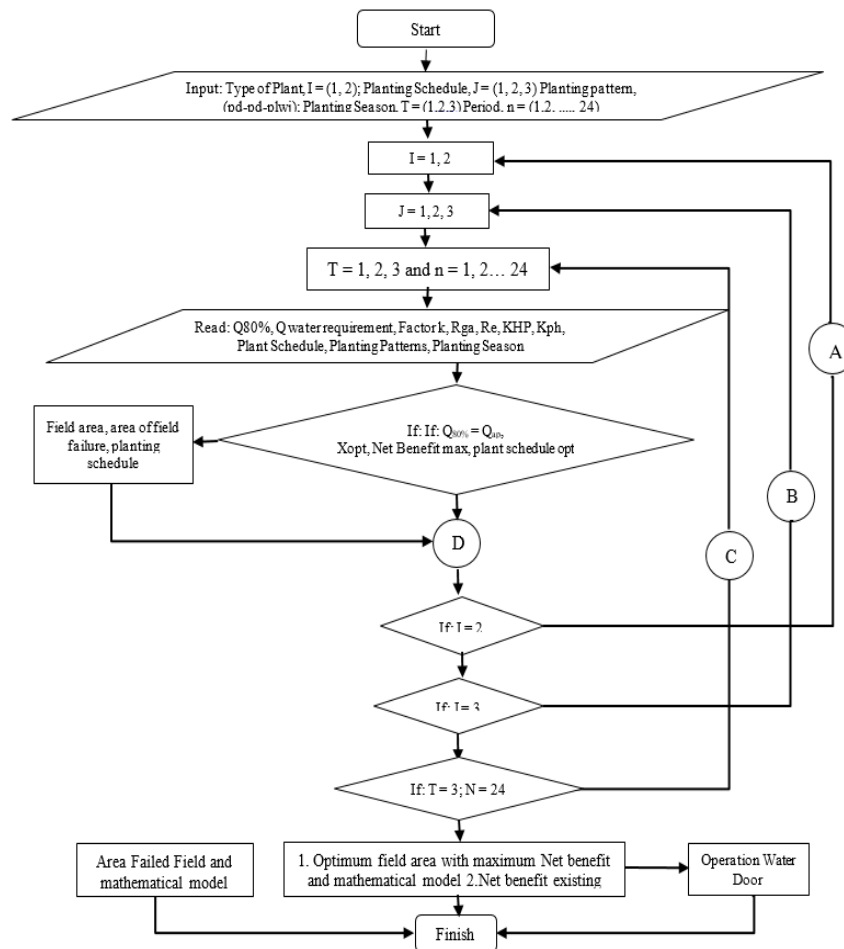
The research materials are field data, climatology and climate data, secondary data of water availability and data of water demand analysis. Data on global cropping plan and tertiary plot data of Cimulu irrigation area. Data planting plan from PSDA will be analyzed and juxtaposed with existing existing planting system in the community. The data were analyzed based on the diagram depicted in figure 2.

## 3. Results and Discussion

### 3.1. Shaping parameters design optimization

Irrigation is the use of water on the ground for the purpose of providing the necessary fluids for the growth of the plants. The water is derived from five sources, namely (1) precipitation; (2) atmospheric water other than precipitation; (3) flood waters; (4) groundwater; and (5) irrigation [1]. Irrigation area is the unity of territory or the expanse of field that gets water from one irrigation network. Water allocation is a concern in developing countries where water resources are limited and demand is greater with more parties [8]. Surface irrigation is an irrigation system that taps water directly in the river through a weir building or through a free intake building and then irrigation water is drained by gravity through the channel to the farm [9].

Optimization is a process to achieve an ideal or optimal result (an effective value that can be achieved). Optimization can be interpreted as a form of optimizing something that already exists, or design and make something optimally. Optimization of water use for irrigation field can be regarded as the efficiency of irrigation, also one of energy saving, water use efficiency and energy use efficiency are the two main focuses of the latest innovations on smart irrigation and smart grid [10]. The irrigation water distribution problem usually occurs in the furthest irrigation area of intake water. Lack of irrigation water is a frequent challenge in the furthest channel [5].



**Figure 2.** Flowchart of the data analysis.

Optimization of irrigation water is a very important component in irrigation water management [11], then it is said that optimization will be achieved if there is water balance between water availability and irrigation water requirement. The parameters of the optimization design-builder in this research are as follows:

- Determine the alternative planting schedule before and after the existing planting schedule with a period of 15 (fifteen) daily so that can be made 24 planting schedule including the existing planting schedule.
- Determine alternative cropping pattern and compare it with existing cropping pattern and cropping pattern which has been determined by PSDA Center of Citanduy River Region in Tasikmalaya and Tasikmalaya Regency.
- Identification of parameters affecting the area of field failure, eg, planting schedule, available water debit, irrigation water needs, irrigation area, effective rainfall, and so on.
- The operation of the sluice gate should be considered especially in the intake building, the 1st door building, and the door of the building for the review in order to minimize the risk of field failure,
- Relation of planting schedule, available water debit, irrigation water requirement to field failure risk is built as the initial stage in making dynamic system design.

The objective function of this research is to maximize the profit of agricultural product (KHP) from irrigation area which can be compiled from the following equation:

$$(KHP)_{opt} = \sum K_{ijT} A_{ijT} - RgL_{ijT} \quad (1)$$

Where:

- $KHP_{opt}$  = optimum agricultural yields (Rp)  
 $K_{ijT}$  = profit per hectare obtained from each plant type i with planting schedule j in one planting season T (Rp./hectares)  
 $A_{ijT}$  = decision variable (optimal area of each plant type i with planting schedule j on one planting season T (hectares)  
 $RgL_{ijT}$  = cost of failure of planting field for each type of plant i with planting schedule j on one planting season T (Rp.)

Profit from Agricultural Product (KHP) is the result of multiplication of the profit/ha of each type of plant with planting area in one year of planting season (production price is considered fixed for each planting schedule). So that KHP is calculated with the following formula:

$$(KHP)_{iT} = K_{iT} A_{iT} \quad (2)$$

Where:

- $KHP_{iT}$  = benefit of plant i in planting season T (Rp.)  
 $K_{iT}$  = plant profit per hectare during planting season T (Rp./hectares)  
 $A_{iT}$  = plant area i in the planting season T (hectares)

The cost of field default risk is a function of the risk index of water failure, the risk of water failure, the reliability, the water discharge, the reliable water debit, the area of field and the profit per hectare.

$$RgL = f^* (IRga, Rga, Re, Q_{ap}, Q_{an}, A, K_{ph}) \quad (3)$$

Where:

- $RgL$  = The risk of field failure  
 $IRga$  = Risk index failed water delivery  
 $Rga$  = Risk of failure of water delivery  
 $Re$  = Reliability  
 $Q_{ap}$  = Discharge water debit  
 $Q_{an}$  = Dependent Discharge  
 $A$  = Field area  
 $K_{ph}$  = The profit of plants per hectares

The equation approach for the cost of plant field failure risk for each planting season j in effective rainfall h% and planting area A is as follows:

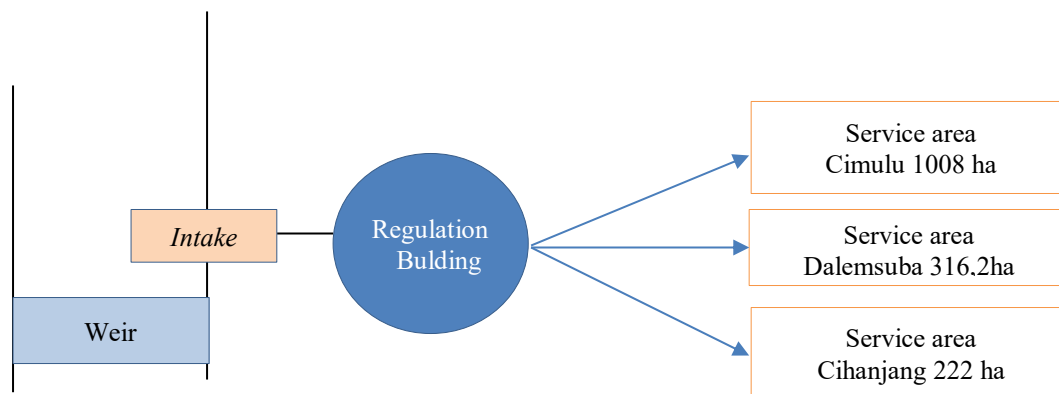
$$RgL_{jhx} = IRga \cdot Rga \cdot \left( 1 - (Re)^{\frac{Q_{ap}}{Q_{an}}} \right) \cdot A \cdot (K_{ph}) Rp \quad (4)$$

Where:

- $RgL_{jhx}$  = cost of failure of planting field for planting schedule T on effective rainfall h% and planting area A ha (Rp.)  
 $IRga$  = risk index failed water delivery  
 $Rga$  = risk of failure of water delivery  
 $Re$  = Reliability  
 $Q_{ap}$  = the need for irrigation water in the building (m<sup>3</sup>/sec)  
 $Q_{an}$  = Definitive of Mean discharge (m<sup>3</sup>/sec)  
 $A$  = Field area (hectares)  
 $K_{ph}$  = profit per hectare (Rp/hectares)

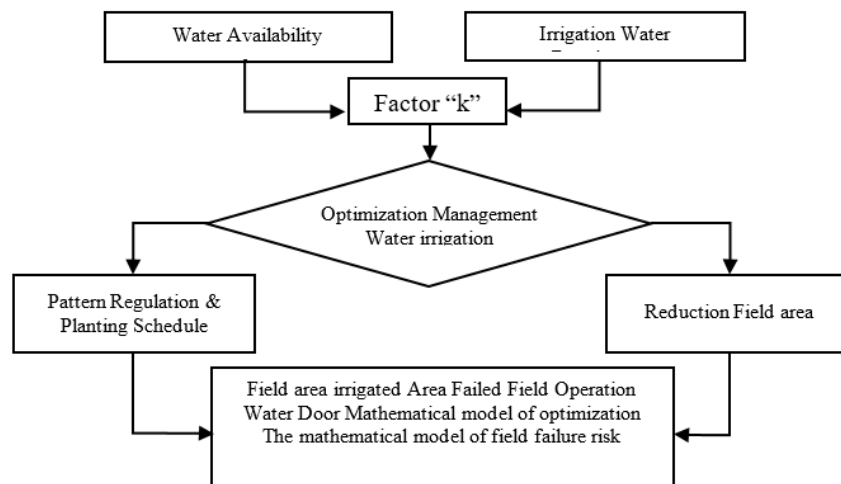
### 3.2. Diagram design and relationship between parameter

Steps and phases of thinking are carried out as follows: (1) collecting data for analysis of the availability and need of irrigation water in the study sites; (2) analyzing the availability of water at the intake; (3) conducting effective rain analysis; (4) conducting irrigation water demand analysis for various planting schedule regulations; (5) conducting optimum analysis of irrigation water management by regulating the field area for various planting schedules; (6) analyzing optimization results to determine the best planting schedule and field area; (7) determining decision-making and inferring the extent of field failure that may occur. Optimization analysis of irrigation field irrigation, field failures and watergate operations can be performed on each building for and intake. For the test phase in this research, the simulation was done on the building intake and building for the first, as in depicted in figure 3.



**Figure 3.** System simulation trial scheme.

Based on the results of the search for the dominant factors that affect the optimization of water management to reduce the risk of field failure, the initial design is obtained as can be seen in the figure 4.



**Figure 4.** Initial design diagram.

Based on the results of the research steps, the initial design of optimization of irrigation water management to reduce the risk of field failure. The design shows the dominant parameters that affect the optimization of irrigation water management to reduce the risk of field failure. Further research needs to be done to present and perform simulation calculations as well as to determine the validity of the design and mathematical models for the various existing conditions created.



#### 4. Conclusions

Based on the simulation result and some analysis from the mathematical model, it can be concluded that the optimum condition is reached at the time of water equilibrium condition (water balance). The condition of water equilibrium is defined as the total availability of water in the year is used and the same or close to the irrigation water requirement throughout the year. At optimum condition is reached, hence can get wide of irrigation area optimum that can be irrigated so can also know the area of irrigation field at risk of failure.

The design of this wake can analyze and compare the condition of global planting plan which is recommended by the government with the traditional farming condition of the farmer community and also offer an alternative planting system.

The value of agricultural production prices obtained is still assumed at the price of production per hectare so it is considered the same throughout the year, it needs to be analyzed further by including the time dimension for the price of agricultural production.

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