Development of application tools for determining cropping patterns based on water availability

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Abstract. Innovative irrigation is a vital factor in increasing water efficiency, gaining benefits, and reducing environmental burdens. Fulfilling irrigation water demand appropriately from time, space, quantity, and quality is the main factor in the irrigation water distribution pattern. A simple information system process, transparent and real-time reporting can reduce water sharing conflicts and improve irrigation operator performance. This research aims to determine the planting area refers to water availability through an automatic calculation application, where the water distribution is carried out based on the condition of the plant's water demand at that time and several days after. The process of collecting the latest data by installing sensors or recording devices related to the analysis of water demand and availability parameters, such as climatological conditions, plants, and water in the rice fields and their sources, was needed as an input process the application. When the automation of operations operates, sensors on the rice fields plots send information directly to data companies that perform information analysis and send agronomic instructions to machines that regulate the release of the amount of water to the motion weir (smart agriculture management system). The way for determining the planting area and planting pattern calculated using the calculation application of the irrigation water demand, which developed with potential evapotranspiration values, reliable rain (R80), crop coefficient (Kc), and dependable discharge data (Q80) as the input data. This system's output data consist of a table of irrigation water demand, a graph of the relationship between irrigation water demand and discharge availability for a year.

Keywords: Irrigation water distribution pattern, smart agriculture, water demand application tools.

1. Introduction

Food security forces us to make agricultural production efforts through quick and accurate decision making by planning irrigation water distribution patterns during planting periods I, II, and III. The planning of irrigation water distribution patterns needs to pay attention to water availability as the intake source as the uptake and planting schemes. In the real condition, farmers often experience shortages of water supply, especially during planting period III. One factor is the mismatch of farmers'
cropping patterns and irrigation water distribution patterns. Determining the cropping pattern consists of determining the type of crop, planting schedule, and planting area orienting towards increasing agricultural productivity by relating it to the water availability factor.

The Indonesian government should utilize neglected agricultural land to prevent food crises due to the threat of drought in the program "Catch up target" A million hectares "of rice fields. Additional agricultural land is needed to increase agricultural production (Koran Tempo, May 5, 2020 edition). Previous research on improving water-saving irrigation entitled Prospects and difficulties of innovative practices by Les Levidow et al. (2014) has been investigated options, incentives, and difficulties for improving water-saving practices. The study results are a management system that can be carried out by stakeholders, both system operators and water user farmers, to exchange information so that irrigation water can be applied sustainably. In 2006, Fatchan N analyzed the practice of providing irrigation water by the gatekeeper and the irrigation network system performance in the Pijenan irrigation area's tertiary plot. The factors that influence providing irrigation water to paddy fields consist of significant rainfall factor (Renfro method, method of the department of public works, and Indian method), plant consumptive water use, percolation, and irrigation efficiency. The study results show that the calculation of providing irrigation water has met the exact criteria for the amount and time of planting period I, not right in planting period II, and not right in planting period III.

Girisha K. et al. (2011) has evaluated groundwater sensors' accuracy for irrigation scheduling, which aims to conserve freshwater in the Trans-Pecos candlenut planting area. Water use efficiency can be significantly improved because the scheduling irrigation based on soil moisture conditions using three low-cost groundwater sensors, namely ECH2O-5TE, Watermark 200SS, and Tensiometer model R, to monitor the volume of groundwater content (θv) can save irrigation water. The study results show that the three sensors still require site-specific calibration to improve their accuracy in estimating groundwater content data. In 2018, Dadan R evaluated the irrigation operation management system (SMOI) in the Bondoyudo irrigation area. The simulation results show that the SMOI can improve water provision accuracy in predicting irrigation water needs, but SMOI has not the best result in improving water provision accuracy than the actual irrigation water needs. The calculation of water requirements on manual blank and SMOI has not accommodated the actual climatological condition's variability. In 2018, Wahyu W performed another research related to the selection of software system development method, namely comparing the selection of the employee's information system development method (SIMPEG) with three models/methods, including the waterfall model, Rapid Application Development (RAD), and Prototype in terms of advantages and weakness. This study aims to assist information systems developers in implementing system development, especially information systems for employees with the right methodology selection.

This research introduces the application software to calculate the irrigation water demand based on a website to shorten the calculation process with simple input and produce maximum agricultural land area. The water distribution pattern has been analyzed based on the used cropping pattern and then relates it to water availability at the intake, which referred to the Irrigation Planning Criteria Standard (KP-01) 2013 in Indonesia. Development process uses the PHP programming language, by Raharjo 2015. Application development considers the many parameters in calculating irrigation water demand in Indonesia with complicated steps. This application summarizes and speeds up the counting process with simple input but maximum output and easy to understand. The software trialed in the technical irrigation network of the Serayu Irrigation with an area of 20,795 hectares across, Banyumas, Cilacap, and Kebumen districts. The irrigation water comes from the Serayu motion weir.

2. The basic concept of the system

Smart water management is necessary as an innovation to support resilience and better urban planning. Hopefully, the smart water management application for irrigation water management can improve operational performance and water distribution accuracy. A recording sensor can generate higher data validation and more updated so that the water demand plan's analysis can calculate faster. The input
data system developed using actual data, but the whole system compiled using the standard calculation in planning at the application's build-up stage. Analysis of irrigation water demand was calculated as a control in the coding in the build-up of application. The model approach was systematically and sequentially gradually or "Linear Sequential Model or Waterfall Development Model." The stages are as follows:

- The Primarily analysis. The primary analysis includes data collection and identification of problems regarding the distribution of irrigation water in the Serayu irrigation area and system requirements focused on making water demand analysis applications. The analysis stages carried out are:
  a) Analysis of irrigation water demand for paddy per hectare (ha)
  b) Analysis of irrigation water demand for Palawija per hectare (ha)
  c) Recap of used irrigation water demand for paddy and palawija per hectare
  d) Recap of Serayu irrigation area service area per the main channel.
  e) Water discharge availability analysis in the intake.
  f) Analyze the total water demand for plants by multiplying the analysis of used plant water demand and the service area's total.
  g) Relate the total plant water requirement used with the available discharge at the intake. Based on these results, a suitable cropping pattern option selected according to the classified options consisting of Option 1 (Paddy-Paddy-Paddy), Option 2(paddy-paddy-Palawija), and Option 3 (Paddy-Paddy-Palawija), and the three options applied without reducing the area of the irrigation service area.

- Design. At this stage, Context Diagrams, Data Flow Diagrams (DFD), Entity Relational Diagram (ERD), database design, table structure designer, and application interface design, as expected, were build-up.

- Coding, implement the design results in a form that can be read and understood by a computer.

- Model verification and validation are criteria built to evaluate the flowchart model, internal logic, and the conceptual model representation to fit reality.

- Program testing. Program testing activities have to ensure that all commands have tested so that every input function will produce the desired output to minimize errors.

Figure 1. Waterfall development model (Pressman, 2015)

3. Application model for calculate the irrigation water demand

The system model of irrigation water demand implemented in the Serayu irrigation area with the following parameters:
3.1. Parameterization

Plant parameter

Irrigation water demand

\[ \text{KAI} = \frac{(E_{tc} + IR + WLR + P - Re)}{E_f} \times A \]  

Plant consumptive use

\[ E_{tc} = K_c \times ET_0 \]  

Effective rainfall for paddy

\[ R_{\text{eff, paddy}} = R_{80} \times 70\% \]  

Effective rainfall for palawija

\[ R_{\text{eff, palawija}} = R_{80} \times 50\% \]  

Percolation

\[ P = 1 - 3 \text{ mm/day} \]  

Water demand for land preparation

\[ IR = \text{look at table 1, obtained from } M = E_o + P \]  

Irrigation efficiency (table 2)

Water layer replacement (WLR) is replacing inundation water in rice fields with new and fresh irrigation water. The water layer's replacement was carried out after fertilizing twice each 50mm or (3.3 mm/day) for one month and two months after transplantation.

Water demand in the fields

\[ \text{NFR} = E_{tc} + P - R_{\text{eff}} + WLR \]  

Net water demand at the intake

\[ \text{DR} = \frac{\text{NFR}}{8.64 \times E_f} \]  

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KAI Irrigation water demand (l/s)

A Irrigation service area (hectare)

Et_c consumptive use (mm/hari)

K_c Plant coefficient

ET_0 The amount of plant evapotranspiration (mm/day)

R_{eff} Effective rainfall for paddy (mm)

R_{80} Rainfall of 80% probability (mm)

IR Irrigation water demand at the rice fields level (mm/day)

M Water demand for replacing of water losses cause evaporation and percolation in the saturated land (mm/day)

E_o Evapotranpiration of open water (estimated at 1.1)

P Percolation

T Time to land preparation(day)

S The amount of water demand for saturation process and the water layer about 50 mm

WLR Water layer replacement(mm/day)

DR Net water demand at the intake (l/s/ha).

NFR Net water demand in the fields for paddy (mm/day).

\[ \frac{1}{8.64} \] Unit conversion rate from mm/day to l/s/ha.

E_f Total of the Irrigation efficiency (%).
Table 1. Water irrigation demand for land preparation (IR)

| Eo + P mm/day | T = 30 day S 250 mm | T = 45 day S 250 mm | Eo + P mm/day | T = 30 day S 250 mm | T = 45 day S 250 mm |
|--------------|---------------------|---------------------|--------------|---------------------|---------------------|
| 5            | 11.1                | 12.7                | 0.4          | 9.5                 | 8.5                 |
| 5.5          | 11.4                | 13                  | 8.8          | 9                   | 9                   |
| 6            | 11.7                | 13.3                | 9.1          | 10.1                | 9.5                 |
| 6.5          | 12                  | 13.6                | 9.4          | 10.4                | 10                  |
| 7            | 12.3                | 13.9                | 9.8          | 10.8                | 10.5                |
| 7.5          | 12.6                | 14.2                | 10.1         | 11.1                | 11                  |
| 8            | 13                  | 14.5                | 10.5         | 11.4                | 11                  |

Source: KP-01, Attachment II, 2013

Table 2. Irrigation efficiency based on National Irrigation Planning Standard

| Channel        | Irrigation efficiency (%) |
|----------------|---------------------------|
| Primary        | 75 – 80                   |
| Secondary      | 65 – 75                   |
| Tersier        | 50 – 65                   |
| Total          | 60                        |

Source: National Irrigation Planning Standard (KP-01), 2013.

Table 3. Plant coefficient (Kc) based on FAO

| Month | Paddy Standard varieties | Paddy Super varieties | Soybean 85 hari | Corn 80 hari |
|-------|--------------------------|-----------------------|-----------------|--------------|
| 0.5   | 1.10                     | 1.10                  | 0.50            | 0.50         |
| 1.0   | 1.10                     | 1.10                  | 0.75            | 0.59         |
| 1.5   | 1.10                     | 1.05                  | 1.00            | 0.96         |
| 2.0   | 1.10                     | 1.05                  | 1.00            | 1.05         |
| 2.5   | 1.10                     | 0.95                  | 0.82            | 1.02         |
| 3.0   | 1.05                     | 0.00                  | 0.45            | 0.95         |
| 3.5   | 0.95                     |                       |                 |              |
| 4.0   | 0                        |                       |                 |              |

Source: (Directorate General of Water Resources, Bina Program 010, 1985 in the KP-01, 2013)

3.2. Program analysis

The program analysis explains as follows:

- The stage of analysis
In this stage, the program and the technology option that will be developed was to analyze. The technology was chosen is a website because it was easy to use and access. The system in this application uses PHP language programming and MySQL.
- The stage of build a storage/database
The first step in these stages is to prepare the storage media using the MySQL database. MySQL database includes the XAMPP installation package by opening the link address at
localhost/PHPMyAdmin. On this page, a storage media and a table can create with a customized name.

- The stage of creating a temporary display

The process of establishing an application begins with creating a template or general appearance of the website. The template used in this application is the bootstrap v.3 framework. In bootstrap, a basic appearance was provided, while other media can be added as needs.

- The stage in creating the program flow code

The programming process was developed using Sublime text tools to assist the code implementation process. Coding was formulated by adding the main flow or functions needed and developed using a browser as a medium for implementing the coding, whether it is what was desired or not. It was consist of ETO, KC, and R<sub>80</sub> data input; input plant data (percolation, rain); evaporation calculation; land preparation; water layer replacement data; total water requirements; R<sub>80</sub> displays; calculate the adequate rain; water requirement (mm/day); water requirement (l/s/Ha); water demand at intake; minimum release discharge of paddy; Minimum release discharge of Palawija; Cropping analysis; dependable discharge 80%, 70%, 10%, and Intake discharge; Channel cropping pattern; Display graphs; Optimization of planting area.

- Evaluation testing program stage

In this stage, the analysis results have to compare the analysis results with existing results. In this stage, the user must check the algorithm or function used according to the desired result. The checking stage was carried out by checking the results of existing calculations in Excel with programmed results.

3.3. Manufacture specifications

Specification description of the application in the Water irrigation demand development in Serayu irrigation network as follows:

**Application of Water Demand Calculation**

| Specification       | Details                  |
|---------------------|--------------------------|
| Programming Language| PHP                      |
| Data base           | MySQL                    |
| RDBMS               | PHPMyAdmin               |
| Framework CSS       | Bootstrap 3.3            |
| Technology          | Web Base                 |
| Tools:              |                          |
| Code Editor         | Sublime, Notepad ++      |
| Server              | Apache                   |
| Build Tools         | XAMPP                    |
| Hardware:           |                          |
| Processor           | I3, 4001 U               |
| Ram                 | 4 Gb                     |
| Input               | Mouse, Keyboard          |
| Hardisk             | 250 Gb                   |

3.4. Installation process

Software installation process as follows:

1. The XAMPP installation. The XAMPP installation is used for the server installer package and the database used, Figure 2.
2. Start Apache and MySQL. It is the process of running the Apache service as a server and MySQL as the database, Figure 3.

3. Web address access: localhost/PHPMyAdmin. It is opening PHPMyAdmin’s initial settings for the database creation process, Figure 4.

4. Creating a database is following the previously created database with the file name "db_kneeds_airSerayu." Through the database menu, then continue to "Create," Figure 5.

5. Import database (db). The step is by selecting the import menu and selecting the database name in our application, which previously copied into c:/xampp/htdocs. In the folder "si_kebutuhan_air_serayu/db".

6. Copy the project to the server address. The project has to copy into c:/xampp/htdocs as shown in Figure 6.

7. Run the program. Run the program according to the folder name Localhost/si_kebutuhan_air_serayu, as shown in Figure 7.

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![Figure 2. XAMPP installation](image1.png)  
![Figure 3. Start Apache and MySQL](image2.png)  
![Figure 4. Web address access](image3.png)  
![Figure 5. Create a database](image4.png)  
![Figure 6. Copy program process](image5.png)  
![Figure 7. Run the application](image6.png)
3.5. Software operation system
The program operation system consists of input parameters and output tables for irrigation water demand for the optimum agricultural land area for planting periods I, II, III, and a graph of the relationship between irrigation water demand and water availability at the intake.

Input parameters
a. Plant’s data, consist of Plant’s master and data analysis.
   - Master Tanaman
     Plants data of paddy and Palawija with the Re value of each is about 70% and 50%. In "Olah Data Tanaman,” enter the type of plant, the percolation value, and the percentage of adequate rain (can be changed and adjusted in the action column), Figure 8.
   - Data analysis
     Before running the analysis, the input parameter of plants demand for each paddy and Palawija have to fill in the available slots, as shown in Figure 9. It was used to change the type of plant with input in the action column in the form of a plant name, and type. The input parameters consist of Eto, Kc, and R80 for the season crop I (MT-I), the season crop II (MT-II), and the season crop III (MT-III).

![Figure 8. Dashboard of “Master Tanaman” visualization](image)

![Figure 9. The dashboard of data input of plant water requirements per planted area.](image)
Table 4. Value of $E_{to}$, $K_c$, dan $R_{80}$ for input data

|       | Eto (7.5 LS 109.2 BT) | Note |
|-------|------------------------|------|
| Jan   | 5.31                   |      |
| Feb   | 5.28                   |      |
| Mar   | 4.94                   |      |
| Apr   | 4.65                   |      |
| May   | 4.61                   |      |
| Jun   | 4.43                   |      |
| Jul   | 4.14                   |      |
| Ags   | 4.41                   |      |
| Sep   | 4.69                   |      |
| Okc   | 4.67                   |      |
| Nov   | 5.22                   |      |
| Dec   | 5.22                   |      |

Paddy coefficient value ($K_c$), 15 daily

|       | 1.05 | 0.95 | 0    | 1.1  | 1.05 | 0.95 | 0    | 1.1  | 0.95 | 0    | 1.1  | I    |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|
|       | 1.05 | 0    | 0    | 1.1  | 1.05 | 0    | 0    | 1.1  | 0.95 | 0    | 1.1  | II   |

Palawija coefficient value ($K_c$), 15 daily

|       | 0.96 | 1.02 | 0    | 0.50 | 0.96 | 1.02 | 0    | 0.5  | 1.02 | 0    | 0.5  | I    |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|
|       | 1.05 | 0.95 | 0    | 0.59 | 1.05 | 0.95 | 0    | 0.59 | 1.05 | 0.95 | 0    | 0.59 | II   |

$R_{80}$ (mm), 15 daily

|       | 58   | 125.5| 98.5 | 40.5 | 58.5 | 0    | 0    | 0    | 0    | 0    | 148  | 32.5 | I    |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|       | 170.5| 113  | 102.02| 27   | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 64   | II   |

b. Input data of availability discharge

The data was inputted manually following the actual data, as shown in Table 5, while the analysis was calculated using the application.

Table 5. Discharge data for input

|       | Serayu motion weir discharge (m$^3$/s), 15 harian |
|-------|-------------------------------------------------|
| Jan   | 192.26                                          |
| Feb   | 171.25                                          |
| Mar   | 248.79                                          |
| Apr   | 321.16                                          |
| Mei   | 160.00                                          |
| Jun   | 93.14                                           |
| Jul   | 78.91                                           |
| Agt   | 43.01                                           |
| Sep   | 35.26                                           |
| Okt   | 23.66                                           |
| Nov   | 163.53                                          |
| Des   | 195.83                                          |
|       |                                                 |
| Jan   | 176.23                                          |
| Feb   | 199.48                                          |
| Mar   | 251.71                                          |
| Apr   | 256.11                                          |
| Mei   | 135.22                                          |
| Jun   | 93.54                                           |
| Jul   | 45.62                                           |
| Agt   | 41.42                                           |
| Sep   | 25.76                                           |
| Okt   | 29.86                                           |
| Nov   | 128.66                                          |
| Des   | 279.23                                          |

II

Table 6. Input data of the basis area of the Serayu irrigation network (hectare)

| Channel name       | A     | Channel name       | A     | Total   |
|--------------------|-------|--------------------|-------|---------|
| Left side 1        | 54.75 | Maosmainchannel    | 3213.7|         |
| Left side 2        | 120.0 | Doplangmainchannel | 1799.9|         |
| Right side         | 85.0  | Sumpluhmain channel| 5324.1|         |
| Cilacapmain channel| 3870.7| Binangunmain channel| 6327.5|         |

Application output

The optimization of the service area can calculate by activating the "Optimalisasi" menu locating below the graph, as shown in Figure 11. Before running the optimization process, the cropping patterns should be filling the box dialogue shown in Figure 10, while the cropping intensity should be input in the box dialogue as a planting plan shown in Figure 11. The optimization process results are a line graph of the relationship between availability and demand discharge and month along the year and a table of the maximum area served by the Serayu irrigation network, as shown in Figure 12. To fulfill the irrigation water demand, the ratio of water availability should be higher than water demand. If water availability in the crop season is less than the water demand, the way to optimize it is to reduce the amount of service irrigation.
Figure 10. Cropping pattern option in a year

Figure 11. The relationship between availability and demand discharge and month along the year
3.6. Smart city-smart water agriculture management

Smart management in water management is an innovation to support resilience and better urban planning. Smart water management in irrigation water management can improve operational performance and the accuracy of water distribution. If the operation management is combining with a data recording device, the data validity will be higher and more up-to-date so that the analysis of the water demand plan can calculate more quickly and precisely.

The application for calculating the irrigation water demand in Serayu developed as a first step in realizing a smart irrigation water management plan connecting to a sensor system as a weather/climatological recording device that can read the value of potential evapotranspiration, rain, and discharge. By the application, the analysis of the calculation of irrigation water demand can be analyzed in an updated, as real according to conditions in the field, so that water utilization becomes efficient.
4. Conclusions

Based on the result and discussions, it can be concluded as follows.
- The process of developing a software system uses the 'Linear Sequential Model or Waterfall Development Model' by Pressman.
- The software system is a web-based application because it has to open a browser like Microsoft Edge or Chrome after the installation process.
- The system operating system is easy to understand and run, making it easier for system operators with simple input.
- The output is easy to understand because it presented a calculation of irrigation water demand during the planting periods I, II, and III with a graph of the relationship between irrigation water demand and irrigation water availability for one year.
- The process of calculating fast and optimizing agricultural land areas can be done quickly and precisely.
- Collaboration of software with a smart agriculture system can be developed by connecting software and weather recording devices.

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