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Application of path analysis to determine the relationship of factors affecting irrigation water sufficiency at the tertiary level of Belintang irrigation system, Indonesia

Murtiningrum* and F Imron

Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Bulaksumur, Yogyakarta 55281, Indonesia

Corresponding author: tiningm@ugm.ac.id

Abstract. Tertiary level is the lowest level in irrigation system which distributes water to agricultural land. The objective of this study was to develop the linkages between irrigation aspects and to measure the strength of aspects related to the adequacy of irrigation water. This study was conducted at Belintang Irrigation System in South Sumatera Province, Indonesia. Data was collected using questionnaires for water users' association as well as through survey to assess infrastructure condition. The state of each aspects was measured using Likert scale according to the predetermined variables. The variables were water availability, infrastructure condition, management, institution and human resources as intervening variable. The dependent variable was irrigation water sufficiency to fulfil planting area target. This research resulted three models, which showed that management has a great influence in mediating the relationship of institution and water availability to water sufficiency in tertiary systems of Belintang Irrigation System. Institution and water availability showed better performance to water sufficiency through management than their direct influence to water sufficiency. This implied that the management development may improve water sufficiency in tertiary level.

1. Introduction

Irrigation is an essential effort to improve food production in order to achieve food sufficiency. Recently the government of Indonesia has constructed and rehabilitated numerous irrigation systems to enhance their capacity in providing water for agriculture. During 2015 to 2019, the government has developed 1 million ha of new irrigation systems and rehabilitated 3 million ha of existing irrigation systems [1].

Currently, the performance of the irrigation system faces various threats [2]. The increase in population causes fierce competition for water use and more water users with complex needs. On the other hand, the population challenges more to the capability of irrigation to support agriculture to provide more food. In addition, irrigation is subject to competition for land use and climate change. The management of the irrigation system has become more complex due to changes in policies, especially in irrigation-related laws and regulations.

Performance of an irrigation system depends on several factors, which can be categorized into five factors, namely water availability, irrigation infrastructure, irrigation management, institutions, and human resources [1,3]. In an irrigation system, the interaction between factors are complex and very specific to the respected system.



The lowest level of irrigation management is the tertiary level. Water User Association is an institution that has authority in irrigation management at the tertiary level. Water User Association members consist of farmers and other water users at the tertiary level. Irrigation management performance at the tertiary level is also influenced by aspects of the availability of water resources, infrastructure, human resources, and institutions. This study aimed to develop the linkages between irrigation management factors and to measure the strength of the relationship between factors related to irrigation capacity to achieve irrigation water sufficiency.

2. Methodology

The study was conducted in Belintang Irrigation System, which irrigates rice field in Ogan Komering Ulu (OKU) Timur Regency, South Sumatera Province. The Belintang Irrigation System draws water from the Komering River through Perjaya Dam in Ogan Komering Ulu District, South Sumatera Province. Komering's irrigation area is 64,200 ha. Irrigation water is distributed through 13.2 km primary canal, 183.1 km secondary canal, and 565 km sub-secondary canal. The irrigation area is divided into three divisions, namely Belintang I, Belintang II, and Belintang III. Figure 1 shows the map of Belintang Irrigation System as part of Komering Irrigation System.

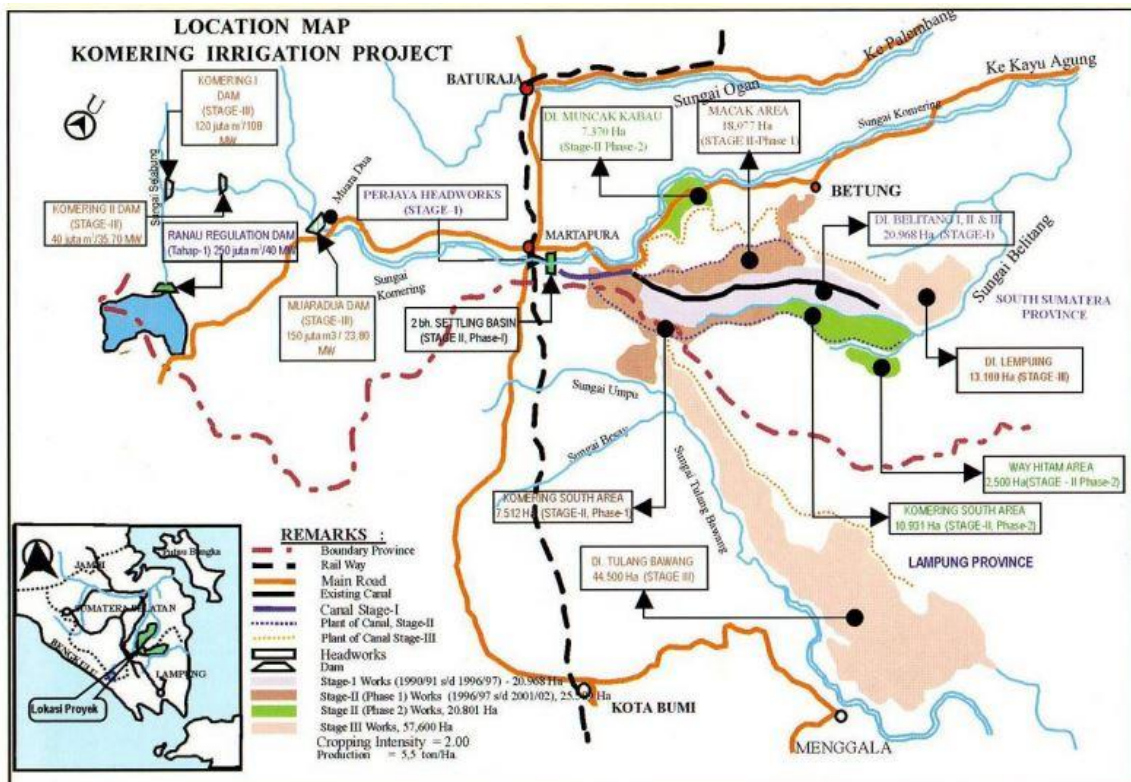


Figure 1. Map of Belintang Irrigation System as part of Komering Irrigation System

The Komering Irrigation Scheme is managed under the Sumatera VIII River Basin Authority. The irrigation system area is divided into eight field offices (observers) which manage an area of 4,000 to 11,000 ha. The field office has one head and some staffs. Each tertiary is managed by WUA.

The instrument employed in this research was questionnaires to collect the responds of WUA as well as irrigation field staffs. The information collected included performance on human resources, institution, finance, and irrigation management variables. Data of each variable was collected by answering some question.

The number of respondents were 60 WUA, consisting of 20 WUA from each division. The responses were assessed using Likert scale according to the predetermined variables. The scale was

ranged from 1 (poor) to 5 (very good). Data collected from questionnaire were then tested for validity and reliability using Pearson Moment method and Alpha Cronbach coefficient. Valid and reliable data was then applied in the regression process to determine the relationship between two variables.

Path Analysis was employed to analysis. The research variables were water availability in water source (X1), condition of irrigation infrastructure (X2), institution (X4), and human resources (X5) as independent variable. Irrigation management (X3) was set as intervening variable. Water sufficiency was set as dependent variable (Y). Two path models were developed to connect between variables as shown in schematic model in Figure 2 and Figure 3.

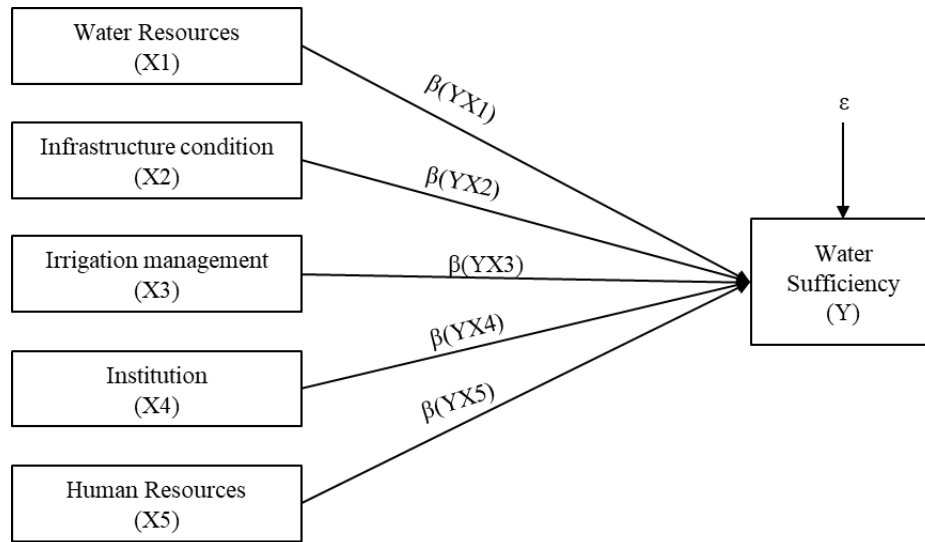


Figure 2. Schematic of Path Model 1

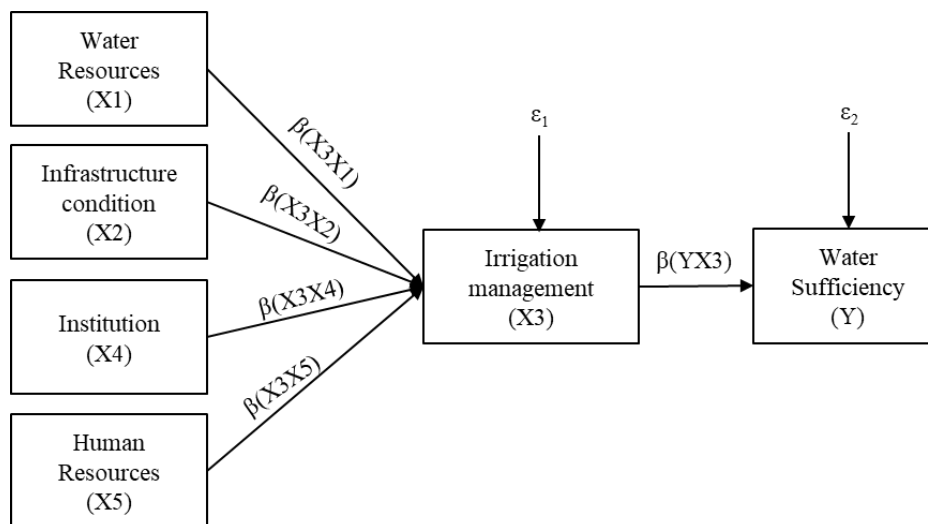


Figure 3. Schematic of Path Model 2

Path analysis described the direct and indirect influences of the independent variables on water availability, infrastructure conditions, institutions, and human resources to water availability as dependent variables. The causal relationship in this study is shown in equation (1) as well as equation (2) and equation (3) for direct and indirect models, respectively.

$$\text{Path model 1: } Y = \beta_1 YX1 + \beta_2 YX2 + \beta_3 YX3 + \beta_4 YX4 + \beta_5 YX5 + \varepsilon_1 \quad (1)$$

$$\text{Path model 2: } X3 = \beta_{31} X3X1 + \beta_{32} X3X2 + \beta_{34} X3X4 + \beta_{35} X3X5 + \varepsilon_2 \quad (2)$$

$$Y = \beta_3 YX3 + \varepsilon_3 \quad (3)$$

Where:

Y : variable of water sufficiency

X1 : variable of water source

X2 : variable of condition of irrigation infrastructure

X4 : variable of institution

X5 : variable of human resources

X3 : variable of irrigation management.

The appropriate model was then tested using the t-test to partially determine the relationship between the two variables. The coefficient of determination (R^2) was then calculated to measure the strength of the model in relating the dependent variables. Path coefficient β was determined using linear regression.

3. Results and discussion

The responses expressed by Water Users Association were then scaled using Likert Scale from 1 (poor) to 5 (very good) as variables X1, X3, X4, X5, and Y. The results of walk through survey were also scaled using the same scale 1 to 5. The average of all responses was shown in Table 1.

Table 1. Characteristics of collected data.

Component	X1	X2	X3	X4	X5	Y
Number of data	60	60	60	60	60	60
Average	3.88	4.00	4.31	3.67	3.50	4.75
Variance	0.105	0.204	0.272	0.514	0.433	0.191
r_{score}	0.661	0.468	0.758	0.853	0.759	0.659

The validity test resulted in the r_{score} shown in Table 1. The r_{table} for $\alpha = 0.01$ and degree of freedom 58 was 0.330 so that all r_{score} of data collected was higher than r_{table} . Therefore, the data of all variables were considered valid. Reliability test was used to measure the consistency of data collection instrument for same occurrences. The data collection instrument was considered reliable when the Cronbach's alpha is more than 0.6. Reliability test resulted Cronbach Alpha value of 0.813 so that the data collection instrument was considered reliable (Table 1).

Path analysis showed the relationship between of direct and indirect variable measurement on the independent variables as indicated by the magnitude of the coefficients. The relationship of direct and indirect variable measurement could be compared.

In this research, the irrigation system consisted of interconnected aspects. There were three hypotheses used in this study based on Figure 2 and Figure 3. First, the direct effects of all aspects to water sufficiency. Second, the direct effects of water availability, infrastructure conditions, institutions, and human resources to irrigation management. Lastly, the indirect effect of water availability, infrastructure conditions, institutions, and human resources on water sufficiency through irrigation management.

Path model 1 in Figure 2 showed the first hypothesis. Path coefficient β was the prediction value of the model variable in the response variable. In the path model 1, the β coefficients was shown in equation 4 and Figure 4. The β coefficients in path model 1 showed that the irrigation management aspect had the strongest influence on water sufficiency in tertiary level with β coefficient of X3 of 0.402. The β coefficient of water resources and infrastructure condition were 0.183 and 0.131, respectively. This indicated that water resources and infrastructure condition have weak relationship with water sufficiency. Meanwhile, institutions and human resources had very weak relationship with

the water sufficiency as shown by the value of β coefficient of -0.052 and 0.081, respectively. The institution had a negative value which showed negative relationship when the institution performed better may result in the worse water sufficiency. However, the relationship was very weak.

$$Y = 0.18(YX1) + 0.13(YX2) + 0.40(YX3) - 0.05(YX4) + 0.08(YX5) + 1.694 \quad (4)$$

$$X3 = 0.44(X3X1) - 0.11(X3X2) + 0.24(X3X4) + 0.15(X3X5) + 1.67 \quad (5)$$

$$Y = 0.475(YX3) + 2.703 \quad (6)$$

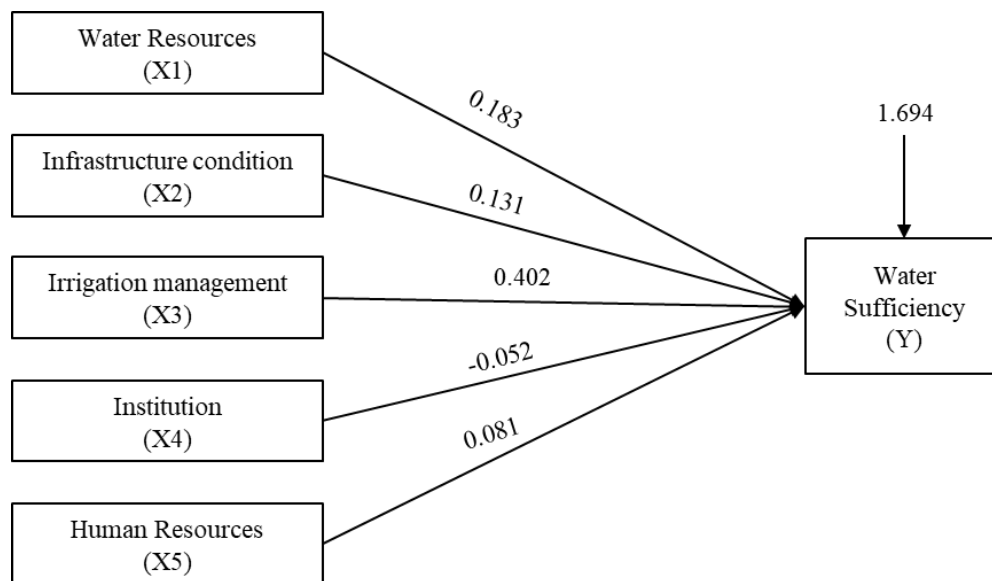


Figure 4. Diagram of Path Model 1

The path model 2 was developed to describe the indirect path model of water resources, infrastructure conditions, institutions, and human resources towards water sufficiency. The β coefficients in the relationship were indicated in equation (5) and (6), as well as Figure 5. The regression analysis showed that β coefficients were generally higher than those of path model 1. The strongest influence was shown by water availability with β coefficient of 0.437. The institution and human resources had better influence on water sufficiency, although they are still weak. The β coefficients of human resources and institution and human resources were 0.238 and 0.147 respectively. The infrastructure conditions had a negative β coefficient. Poor irrigation infrastructure can still result in water sufficiency as long as irrigation was well managed and water availability in the source is good. However, the β coefficient of infrastructure was -0.112 or very weak. The irrigation management maintained β coefficient of 0.4 which showed a strong relationship between irrigation management and water sufficiency.

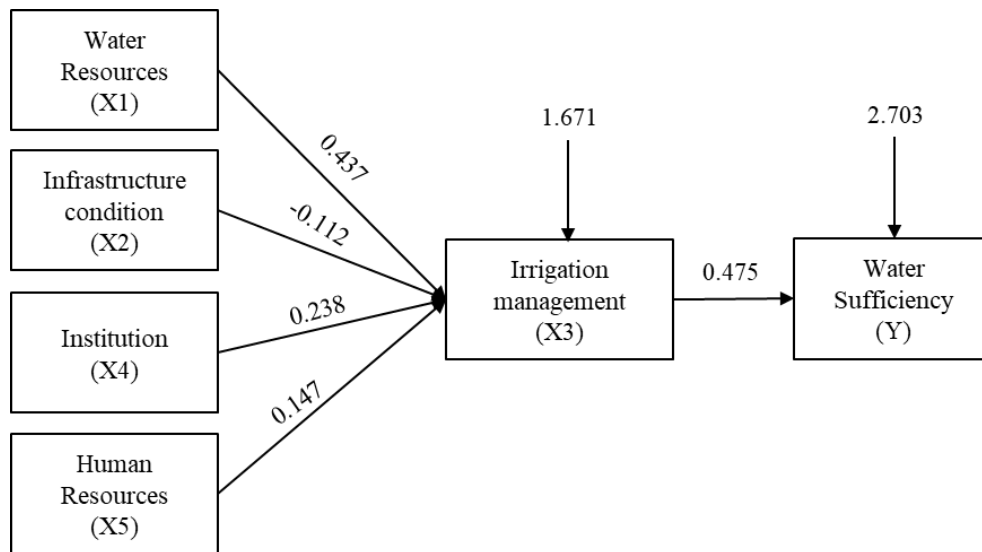


Figure 5. Diagram of Path Model 2

Combination of both models showed that irrigation management had a great influence in mediating the relationship of water availability, institutions, and human resources on water sufficiency in Belitang Irrigation System. Water availability, institutions, and human resources showed a better performance on water sufficiency through irrigation management than their direct influences without intervening variable. This implied that the development of irrigation management in tertiary level may improve the performance of irrigation system to supply sufficient water to the tertiary blocks.

4. Conclusion and recommendation

The research resulted in two models:

Path model 1

$$Y = 0.18(YX1) + 0.13(YX2) + 0.40(YX3) - 0.05(YX4) + 0.08(YX5) + 1.694 \quad (4)$$

Path model 2

$$X3 = 0.44(X3X1) - 0.11(X3X2) + 0.24(X3X4) + 0.15(X3X5) + 1.67 \quad (5)$$

$$Y = 0.475(YX3) + 2.703 \quad (6)$$

The models showed that irrigation management has a great influence in achieving irrigation water sufficiency in tertiary level. Therefore, it was recommended to improve irrigation management to achieve water sufficiency.

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