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Impact of Irrigation on Agricultural Growth and Poverty Alleviation in West Java Province, Indonesia

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ABSTRACT

Irrigation in developing countries tends to be stereotyped as equity reducing, in competition with other uses for scarce water resources, often negatively impacting disadvantaged groups. This study aims to clarify the linkages between irrigation and poverty by offering an objective review of recent research on the subject. The key questions addressed herein are: (1) what is the role of irrigation development and management in poverty alleviation? (2) what are the linkages and pathways through which irrigation contributes to poverty alleviation? (3) what is the magnitude of anti-poverty impacts of irrigation? And (4) what are the critical determinants of anti-poverty impacts of irrigation? Our review focuses on topical empirical research studies in West Java Province, Indonesia. Agricultural intensification through the practice of irrigation as a strategy for poverty reduction is examined. There are four inter-related mechanisms through which irrigated agriculture can reduce poverty. These are improvements in the levels and security of productivity, employment, and incomes for irrigating farm households and farm labor; the linkage and multiplier effects of agricultural intensification for the broader economy; provision of opportunities for diversification of rural livelihoods; and multiple uses of irrigation supply. There are also significant risks that poorly designed and managed irrigation can negatively impact on poverty. It is concluded that two factors of production (irrigation and literacy rate) have a larger role in the overall rural development and poverty alleviation process in a region, as also clearly illustrated in this study's regression results.

***Keywords*:** Irrigation, agriculture, poverty, rural livelihood, West Java Province

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1. INTRODUCTION

Agriculture is an important sector in economic development, considering its function and role in providing food for the population, industrial raw materials, food and energy sources, and rural people's livelihoods. This sector has a significant contribution to the formation of Gross Domestic Product (GDP), increased foreign exchange, and increased welfare of farmers so that agricultural development can be the driving force and support for the national economy [1-5]. However, the growth of the agricultural sector in Indonesia's economic growth has decreased. [3-8] in his writing regarding the Indonesian agricultural sector's performance in the 2012-2016 period, argues that the growth of the agricultural sector has decreased by more than 1%. In 2012, the agricultural sector's growth was at 4.59% but dipped to 3.25% in 2016.

The agricultural sector's performance is related to irrigation management. Its infrastructure as a form of management of exploitation and distribution of irrigation water, especially in dry or impoverished areas, has a water scarcity period to increase agricultural crop production [3-8]. Irrigation infrastructure and facilities are important factors in the farming process in the agricultural sector [8-10].

Irrigation infrastructure determines the distribution of irrigation water, which impacts the quantity of water available for crops, especially rice. A good irrigation network system will contribute to the optimization of national food production [11-15]. Irrigation networks are channels, buildings, and complementary structures that area unit needed for the provision, distribution, provision, use, and disposal of irrigation water [13-18].

Figure 1. West Java Province Map.

Though various studies have very well documented the positive impact of irrigation on agricultural intensification and increased crop yield, the marginal returns of irrigation versus other factor inputs such as farm technology and additional rural infrastructure development are still controversial issues in pastoral development literature. Improved information and understanding of the scale of incremental benefit of irrigation and other factor-inputs to agricultural growth and development and the poverty alleviation process have massive public policy implications for setting rural development policy in a region. This has particularly more relevant in setting irrigation and agricultural investment and financing policies.

This information is also essential, considering the recently increased global public policy priorities and thrusts on poverty reduction strategies [15-20].

In this study, an attempt is made to analyze the incremental impact (input specific effects) of irrigation and other factor inputs on the growth of agricultural productivity of all inputs taken together (i.e., Total Factor Productivity) and their implications on poverty alleviation in the West Java over the last two and half decades. The Total Factor Productivity is also called the productivity of all inputs taken together.

It is different from the conventionally understood productivity measures like crop yield, water productivity, or labor productivity. The study also examines the structure and relative importance of the factors that affect the overtime variation in poverty and rural consumption level across West Java districts. This is done using annual time series and cross-section (government) data analysis techniques across 26 central districts of West Java covering the period from 1995 to 2019, covering more than 90 percent of West Java's agricultural economy [18-22].

The purpose of this paper is to analyze the incremental impact (input specific effects) of irrigation and other factor inputs on the growth of agricultural productivity of all inputs taken together (i.e., Total Factor Productivity) and their implications on poverty alleviation in West Java. This paper first provides a general typology for considering the wide range of mechanisms through which irrigation impacts humans directly and through the environment. It then presents the results of a broad review of published literature focused generally on the measurement of irrigation impact, primarily from the Green Revolution era onwards

2. METHODS

We specified the following logit model that can deal with a binary dependent variable and has a well-established theoretical background. Just as in OLS regression, logistic regression can be used with more than one predictor. The analysis options are similar to regression. One can choose to select variables, as with a stepwise procedure, or enter the predictors simultaneously or enter blocks.

Variations of the likelihood ratio test can be conducted in which the chi-square test (G) is computed for any two models that are nested. Nested models are ones in which a subset of predictors are included in the model. A chi-square test is not valid unless the two models compared involve one reduced (i.e., nested within) the other model [2-6].

The interpretation is similar to OLS regression. Slopes and odds ratios represent the "partial" prediction of the dependent variable. A slope for a given predictor represents the average change in y for each unit change in x, holding constant the effects of the other variable. One model we might consider is:

$$P(D|X_1, \ldots X_k) = p = \alpha + \beta_1 X_1 + \ldots + \beta_k X_k$$

However, if we fit such a model, there is no guarantee that the estimated value of $\underline{p}$ would always be between 0 and 1. Since p is a probability of poverty given specific characteristics, its value naturally has to be between 0 and 1.

The appeal of using a logistic function $f(z) = \frac{1}{1+e^{-z}}$ to data from this study as the dependent variable are:

Eq. 1. Poverty incidence, i.e., % of population below the poverty line by Head-Count Ratio measure.

Eq. 2. Rural per capita monthly avg. consumption (in IDR/person/month, 2003-2004 constant prices).

3. RESULTS AND DISCUSSIONS

The overall growth and technical change in the agricultural sector have massive implications on expanding the region's economic base and poverty alleviation process. Past empirical studies have shown that ultimately the growth in productivity of all factors (TFP) in agriculture is the backbone for alleviating rural poverty in developing countries [19-25]. While summarizing the previous literature on agriculture growth and poverty reduction, [20] points out that agricultural development has a profound impact on poverty reduction in developing regions, including reducing the inequity over time. The actual effect of agricultural growth on poverty varies by nature, region, and period selected for the studies. Though most of the previous studies have unequivocally demonstrated that agricultural productivity growth has a profound impact on reducing poverty in Asia, the existing literature on rural poverty has failed to examine the incremental impact of each of the factor inputs on agricultural productivity growth as well as their marginal impact on poverty alleviation, and rural income enhancement (Detailed discussions on these issues can be found in [26].

Many irrigation impact-related case studies and regional studies in West Java have illustrated that irrigation management has a profound role in the poverty alleviation process [20, 25-28]. Some of the current aggregate level empirical studies in West Java have shown that irrigation access positively impacts poverty reduction [27-30]. However, there is no straightforward relationship between irrigation and poverty alleviation, and the irrigation impact on poverty alleviation depends upon several other intermediate factors [29-31]. Thus, an improved understanding of the structure of the impact of various factors and quantification of each factor's marginal impacts on poverty measures is vital for developing efficient and effective policy instruments in poverty alleviation and rural development programs in general.

The sustainability of agricultural ecosystems and their relationship with economic growth in developing and developed countries is closely related to water management. Water management in the agricultural sector takes a central role, which often creates controversy on allocating sustainable water resources [30-33]. Simultaneously, water resources are becoming increasingly scarce, especially in areas categorized as dry and semi-arid [23, 28, 30-35]. Based on its use, the agricultural sector is the largest freshwater user compared to other sectors. The use of water in the agricultural sector has received significant attention regarding its conservation and sustainability in terms of quantity and quality [28, 34, 36]. It is known that around 20% of irrigated agricultural land has contributed 40% of total agricultural production [20-22, 26, 29].

3. 1. Factors affecting the productivity of all inputs

This study quantifies the marginal impact of irrigation and other factor inputs on all inputs' agricultural productivity and the districts' two key poverty measures. The empirical results (details in the full paper) show no significant growth in the agriculture productivity level when all inputs are used. Their costs are taken together (in terms of economic and technical efficiency) in West Java over the last two decades. This productivity growth of all inputs is different from the simple crop yield or labor productivity. The change in the trend of irrigation land and land and labor productivity changes at all West Java level is illustrated in Figure 2 below.

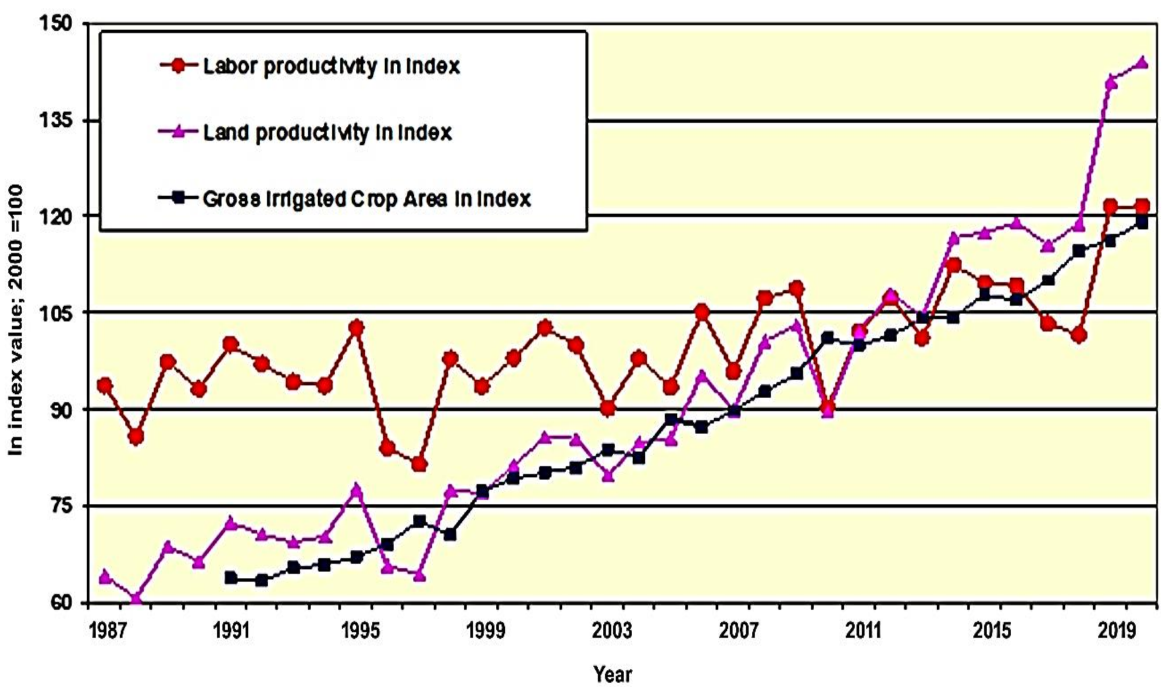

Figure 2. Land and labor productivity change along with gross irrigated cropped area at all West Java Province, 1987 - 2019

The regression results in table 1 show that the marginal impact of the irrigation factor on the growth of productivity of all inputs is positive and significant with the elasticity of 0.32, which is larger compared to the impact of other factors such as fertilizers, HYV adoption rate, and road infrastructure selected in the analysis. This means that a one percent increase in the irrigated area has increased about 0.32 percent in the productivity of all inputs (TFP) in West Java during 1995-2019. This is a very high impact on agricultural productivity than other factors such as fertilizers, HYV, and road infrastructure. The elasticity varies only from 0.04 to 0.09. The impact of rural literacy rate (percent of rural population) is positive and statistically significant in explaining the overtime variation in agricultural productivity of all inputs (TFP) [26-29]. The marginal impact of rural literacy on agricultural productivity is the largest among the analysis variables. This massive impact of rural education is possible because technical change and agricultural productivity (represented by high TFP index), and rural development are directly related to the adoption of improved technology, selection of an appropriate mix of crops and inputs, and timely application of these inputs, including the farmers' ability to effectively process market and price information and farm managerial decisions [29-33]. The impact of variable road infrastructure is also positive and significant, capturing the effects of market access in agricultural and rural development.

3. 2. Factors affecting the poverty rate and per capita rural consumption level

There is a robust spatial dimension to poverty and inequality in the West Java region. Differences exist between urban and rural areas and between different regions; the east side is significantly more deprived than other areas. This phenomenon has prompted successive administrations to adopt a dual approach to poverty reduction that combines social protection to stimulate local economic development through community infrastructure initiatives financed by large-scale fiscal transfers. In 2007, the official poverty head-count ratio in urban areas was 12.5%, compared with 20.4% in rural areas. By 2016, the poverty head-count had fallen to 7.7% in urban areas and 14.0% in rural areas. As a consequence of sustained and rapid urbanization, the urban population exceeded the rural population in 2011, having accounted for just 30.5% in 1990 [33-36].

The study has also analyzed the direct impact of selected factor inputs in explaining the variation in poverty measures (poverty measure in head-count ratio and rural per capita consumption) across the districts for 1995-2019, using the same set of factors used on analyzing the agricultural productivity. The study found that the extent of rural poverty was unequivocally greater in a state with less irrigation, especially in the early 1980s. Moreover, the relationship between rural poverty and irrigation has been decreasing in the recent past. The change in the relationship between irrigation and poverty across the districts in West Java over the last two decades has also been analyzed, as shown in Figure 1. This indicates that the poverty level scale was very severe in the early 1980s, with more than 60 percent of the rural population under the poverty line (head-count ratio) in almost all central and eastern West Java parts. Irrigation development was also deficient in these regions at that time. However, the situation has improved in the early 1990s, where rural poverty is most concentrated in districts like Karawang, Cianjur, and Indramayu, where irrigation is insufficient today. While analyzing the independent relationship between irrigation and rural poverty, there appears to be a strong inverse relationship between the incidence of rural poverty and the percentage of gross cropped area irrigated.

Besides analyzing the role of irrigation in rural poverty through regression analysis, we have also depicted the relationship between irrigation and poverty in the two graphs. The trend of variation in irrigation and the various poverty measures and how they have changed over time is illustrated in Figure 2. The level of irrigation has increased more than double between 1989 and 2019. As can be seen from Figure 2, all the poverty measures have declined unequivocally during these periods. The Head-Count Index (HCI), which measures the percentage of population below the poverty line using consumption expenditures, has reduced over the last three decades. More importantly, the other two poverty measures, the poverty gap index (PGI) and Foster-Greer-Thorbecke (FGT), have declined faster over the last three decades. This means all three rural poverty measures in West Java have reduced during the period, contributed mainly by irrigated agriculture's success over the years.

The poverty reduction potential of irrigation has been well documented [5-8]. The increased output provides additional food for subsistence producers. Price reductions provide substantial benefits to low consumers, mainly since the poor spend a higher proportion of income on food. Many low producers are also net buyers of food and so also benefit in this way. However, the nature and extent of poverty impacts can vary greatly depending on factors such as relative or absolute land size, relative location within an irrigation system (e.g., head or tail end), and structural issues related to the overall institutional and social-economic environment, for example as related to gender, caste, and class [5-11].

Beyond direct production, consumption, and income effects, irrigation also impacts poverty through indirect mechanisms, including increased labor demand, particularly during harvest periods, nutrition and health change, and economy-wide multiplier effects. Whether these impacts are positive or negative is highly contextual. For example, irrigation's employment effects may benefit the landless poor, but inequalities may also widen as output increases and depresses prices received by poor farmers operating in rain-fed conditions. Irrigation may also worsen poverty if it re-enforces land consolidation processes in which low households lose rights, converting marginal and poor farmers to landless laborers [6-12] or if it is associated with displacement of labor mechanization or herbicide use. The development of irrigation can have off-site environmental impacts that are particularly important for the poor. For example, the construction of dams and reservoirs to support irrigation has been associated with displacement costs that disproportionately fall on the poor [5-12]. Irrigation may also reduce environmental service provision upon which the poor rely, such as inland and marine fisheries.

Table 1. Factors determining the variation in poverty measures across 26 districts of West Java Province, 1996-2018.

Independent Variable	Marginal Impact (Poverty Model) Equation 1	Elasticity at Sample Mean value	Marginal impact (Cons. Model) Equation 2	Elasticity at Sample Mean value
Constant	70.87 (29.33)		43.5 (26,13)	
Time trend	-0.50 (5.23)***		0.14 (1.94)**	
Percentage of Gross cropped area under irrigation (GIA/GCA)	-0.37 (7.95)***	0.27	0.21 (5.60)***	0.12
Fertilizer use per cropped area (Kg/ha)	0.03 (0.88)^{NS}	0.03	0.036 (1.47)	0.03
HYV adoption rate (in %)	-0.09 (1.62) *	0.08	0.15 (4.04)***	0.095
Rural literacy rate (%)	-0.18 (1.90)*	0.12	0.18 (2.88)***	0,09

Road density (in km/1,000 km^2 land)	0.005 (1.74)*	0.05	-0.01 (10.55)***	0.10
Adjusted R^2 (Un-weighted)	0.53		0.35	
Number of districts (cross-section)	14		14	
No. of data point for each state	11		11	
Number of observations (unbalanced observations)	148		154	
The sample mean of a dependable variable	46 %		IDR.125/month	

Notes:

Dependent Variable:

Eq. 1. Poverty incidence, i.e., % of population below the poverty line by Head-Count Ratio measure.

Eq. 2. Rural per capita monthly avg. consumption (in Rp/person/month, 2003-2004 constant prices).

1) Values in parentheses are absolute t-statistics; * - significant at 10 percent; ** - significant at 5 percent; *** - significant at 1 percent. F statistics of both the models in Table 1 are significant at 1percent.
2) Both models in Table 1 were estimated as a constant intercept pooled panel model using the Weighted Least Squares technique (GLS regression). The GLS model was further iterated to minimize the mean square errors (MSE). The results are from converged models.
3) Elasticity value is estimated at the sample mean observations (e = dy/dx*x/y). It shows a percentage change in the dependent variation when the independent variable changes by one percentage point.
4) Poverty measures are estimated as the percentage of the rural population under the poverty line at any year estimated by the head-count ratio method.
5) Rural per capita mean monthly consumption illustrates the change in the rural population's purchasing capacity (income) at the constant prices of 2003-2004. This is also another measure of an overtime change (reduction) on the poverty measure in a region.

Irrigation contributes to energy and protein [13-15] and can provide increased incomes or purchasing power to support diet diversity [10-14]. However, the monoculture often associated with irrigation can also reduce the availability of more nutrient-rich crops and increase their costs relative to more great staples. The situation does not need to be the case, however. Small-scale irrigation in Africa has been associated with increases in vegetable production with direct nutritional status benefits, particularly for women and children [6-11]. A variety of mechanisms through which the Green Revolution related increases in production are related to nutritional status is outlined [12]. A more recent review of nutrition-related impacts of irrigation focused on sub-Saharan Africa is provided by [10-12].

As depicted through figures, the regression results also clearly demonstrate the role of irrigation in reducing rural poverty. The regression results analyzing the detailed structure of the impact of factor inputs on variation in poverty measures (HCI) and per capita rural consumption across the districts are given in Table 1. The negative sign of the time trend variable in the poverty model (equation 1), which shows overtime change on the poverty rate trend**,** suggests that West Java's poverty level has unequivocally decreased from 1998 to 2013.

This is also supported by the positive sign of this time trend variable in the consumption model (equation 2), which shows the increasing rate of the rural population's per capita consumption. Among all the variables selected for analyzing the poverty measures in this study, the irrigation factor has the most decisive influence in explaining poverty reduction [4-11].

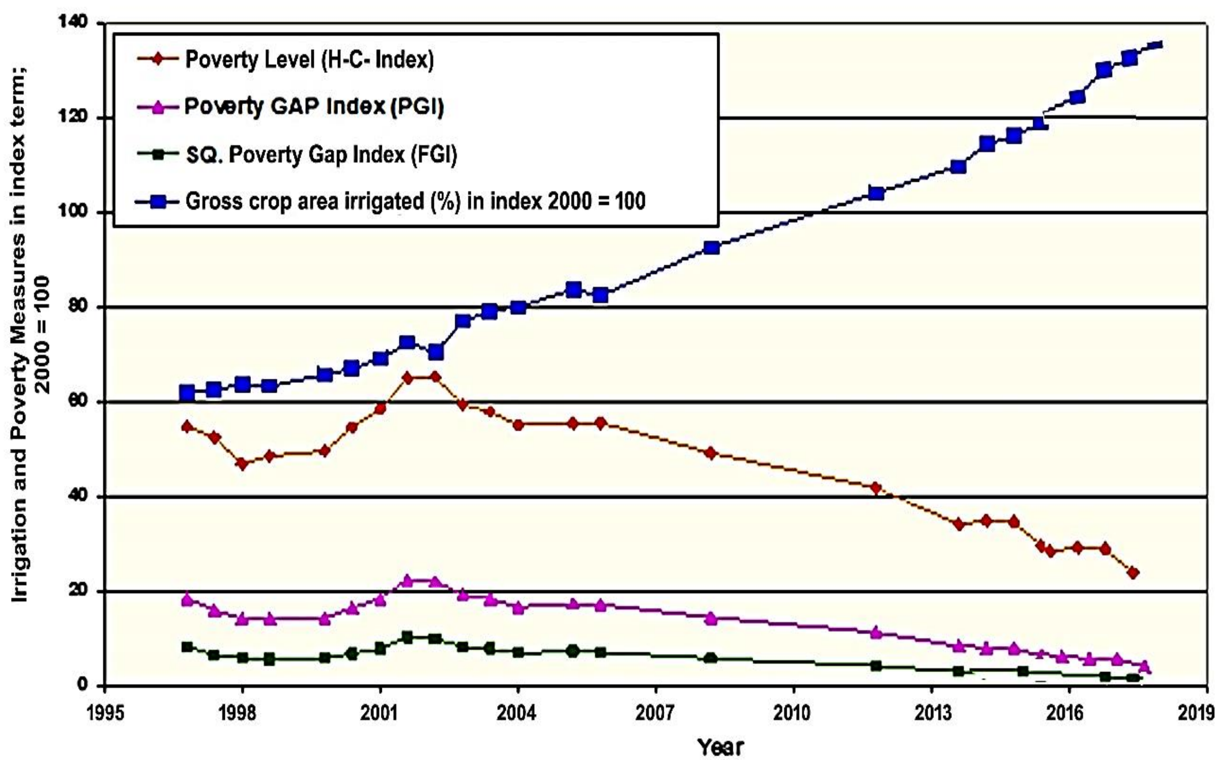

Figure 3. Relationship between irrigation and poverty measures at all West Java Province, 1995 - 2019

Irrigation has even a more massive marginal impact on reducing poverty than the impact of rural literacy. Simultaneously, the rural education factor was earlier found to be strongest in influencing the agricultural productivity across the districts [20-30]. Likewise, the increased HYV adoption and fertilizer use have also played a favorable role in reducing poverty in West Java. Still, their influence on poverty reduction is lower than the marginal incremental impact of irrigation and rural literacy. Unlike in productivity growth, the variable road infrastructure does not play any positive and favorable role in explaining the variation in rural poverty in West Java during the period selected for this study.

Despite controversies in the incremental impact analysis of factor inputs and their contribution to the agricultural growth and rural development process (WCD, 2000), this study has successfully separated these factor-inputs' cumulative marginal impact in the agricultural development and rural development process. The study's empirical results demonstrate that improvement in irrigation and rural literacy rate are the two most important critical factors for the recent growth and the overall development of West Java's agricultural sector. Considering the essential role of agricultural growth on poverty reduction in a region as established by the previous literature [3-13], these two factors of production (irrigation and literacy rate) have a larger role to play in the overall rural development and poverty alleviation process in a nation, as also clearly illustrated in the regression results of this study. The broader impact of rural literacy rate on the interstate variation in agricultural productivity clearly shows the critical role of human capital development in agricultural sector productivity and enhanced farm income [5-9].

The extensive review suggests that there are strong linkages between irrigation and poverty. These linkages are both direct and indirect. Direct linkages operate via localized and household-level effects, and indirect linkages operate via aggregate or subnational and national level impacts. Irrigation benefits the poor through higher production, higher yields, lower risk of crop failure, and higher and year-round farm and nonfarm employment. Irrigation enables smallholders to adopt more diversified cropping patterns and switch from low-value subsistence production to high-value market-oriented production. Increased production makes food available and affordable for the poor [8-14].

The indirect linkages operate via regional, national, and economy-wide effects. Irrigation investments act as production and supply shifters and have a strong positive effect on growth, benefiting the poor in the long run. Further, irrigation benefits also accrue to the poor and landless in the long run, although the short-run relative benefits to the landless and land-poor may be small, as water allocation often tends to be land-based. Despite that, the poor and landless benefit from irrigation investments in both absolute and relative terms. Recent advances in irrigation technologies, such as micro-irrigation systems, have strong anti-poverty potential. Ongoing studies in Asian countries document strong evidence that irrigation helps to alleviate both permanent and temporary poverty. Further, it helps to alleviate poverty in its worst forms, namely chronic poverty [27-42].

4. CONCLUSIONS

The findings of the present study suggest that the future strategy on poverty reduction in rural West Java still largely depends upon how efficiently the irrigation sector is managed and how effectively the level of irrigation access is provided to a large number of farmers in the regions that have still not benefited from the Green Revolution of the 1970s and 1980s. The population's lowest income quintile would also gain more from the irrigation development than the other upper-income quintile of the population just below the poverty line due to increased employment (wage rate increase and employment security) and other feedback effects generated in the rural economy. Thus, irrigation access is a pro-poor strategy to alleviate poverty's severity and gravity in a region, as illustrated from the macro-level aggregate analysis in this study.

In general, irrigation is productivity-enhancing, growth-promoting, and poverty-reducing. Instances of adverse externality effects associated with large and medium-scale irrigation systems point to management issues and call for more comprehensive response mechanisms from the planning and the political community alike. The anti-poverty impacts of irrigation can be intensified by creating conditions or enabling environments to achieve the poor's functional inclusion. These include: (1) equitable access to land; (2) integrated water resource management; (3) access to and adequacy of good quality surface and groundwater; (4) modern production technology, (5) shift to high-value market-oriented production; and (6) opportunities for the sale of farm outputs at low transaction costs. The benefits of irrigation to the poor can be intensified by initiating broader level and targeted interventions simultaneously.

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