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Budget Optimization of the Special Allocation Fund for Irrigation in Indonesia

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Abstract: This research objective is to develop a budget optimization model for the Special Allocation Fund for Irrigation in 2021 based on the good condition of irrigation network areas as intermediate outcome performance. The performance equation function and nonlinear programing with Generalized Reduced Gradient (GRG) Non-Linear are employed to seek the optimum allocation for the selected 43 local governments in this research. With an IDR 314.38 billion available budget in 2021, 533.086 ha of irrigation networks in good condition are expected to be achieved from the distribution of the optimized budget in this research, which increased from 481,431 ha in 2020. Only 39 local governments were considered the best locations to receive the Special Allocation Fund for Irrigation in 2021. This model can be considered as an initial step toward improving the planning and budgeting processes of the Special Allocation Fund for Irrigation. Since this model was developed from a relatively small dataset, the results of this research should be treated with utmost caution. Future research could consider a larger data set to develop outcome performance's budget optimization model, such as improvements to plantation areas. Improvement of how the Special Allocation Fund for Irrigation is planned and allocated has been a concern for years. Many studies and findings have revealed that the distribution of the Special Allocation Fund for Irrigation faces some effectiveness challenges, such as being considered less relevant to strengthening food security and making less contribution to irrigation network conditions.

Keywords: special allocation fund for irrigation, irrigation network, performance equation function, generalized reduced gradient method, non-linear optimization.

印尼灌溉专项拨款基金预算优化

摘要：本研究的目标是以灌溉网络区域状况良好为中间结果绩效，为 2021 年灌溉专项拨款基金开发预算优化模型。本研究采用性能方程函数和广义梯度下降(格栅)非线性非线性规划来寻求选定的 43 个地方政府的最佳分配。2021 年可用预算为 3143.8 亿印尼盾，预计从本研究中优化的预算分配中将实现 533.086 公顷状况良好的灌溉网络，比 2020 年的 481,431 公顷有所增加。只有 39 个地方政府被认为是 2021 年获得灌溉专项拨款基金的最佳地点。该模型可以被视为改进灌溉专项拨款基金规划和预算编制流程的初步步骤。由于该模型是根据相对较小的数据集开发的，因此应极其谨慎地对待本研究的结果。未来的研究可以考虑更大的数据集来开发成果绩效的预算优化模型，例如对种植面积的改善。多年来，灌溉专项拨款基金的规划和分配方式的改进一直是一个值得关注的问题。许多研究和研究结果表

明，灌溉专项拨款基金的分配面临着一些有效性挑战，例如被认为与加强粮食安全相关性较低，对灌溉网络状况的贡献较小。

关键词：灌溉专项资金，灌溉网络，性能方程函数，广义梯度降法，非线性优化。

1. Introduction

Irrigation management in Indonesia has undergone fundamental changes as a consequence of the Big Bang political reform decision in the late 1990s. Decades of centralized government systems were suddenly abolished [1] and converted into decentralization approaches that transfer greater autonomy to provincial and local governments [2], including irrigation management. These reforms were initiated by Law Number 7 of 2004 on Water Resources and Government Regulation Number 20 of 2006 on Irrigation, which was later revised by Law Number 17 of 2017 on Water Resources. In line with the spirit of decentralization, centralized authorities to manage irrigation systems were distributed to three levels of government (central, provincial, local) based on the size and location of irrigation areas [3]. All sudden, local and regional governments were entrusted with a mandate to manage 65.6% of the total irrigation areas in Indonesia [4], whereas the central government is mandated to manage irrigation systems with areas of more than 3,000 ha and cross-province irrigation systems. This new arrangement was completely different from the 1970s-1990s condition in which the central government dominated most of irrigation investment, regardless of the size of the area and location of the irrigation system [5]. Therefore, many provincial and local governments still lack sufficient financial and technical capacities to perform their new assignments in irrigation management.

As a result of political resolution to abandon centralized system, the fiscal decentralization policy was adopted in Indonesia after enactment of Law Number 22 of 1999 on Local Governments and Law Number 25 of 1999 on Fiscal Balance between Central and Local Governments. Financial relationships were formed between the central government and autonomous (provincial and local) governments that received the delegation of former centralized government functions. Budget transfers become an important component of those financial relationships because most provincial and local governments' own-source revenue is insufficient to perform decentralized functions [6]. The Special Allocation Fund Dana Alokasi Khususus (DAK) is a specific purpose budget transfer that is used to finance certain national priorities that have been delegated to provincial and local governments [7]. It was initially distributed in 2003 with very limited priority areas of use, including irrigation. These budget transfers are a consequence of decentralized irrigation authorities which were distributed to provincial and local governments. Due to its significant contribution to rice production and the fact that food security is still among Indonesia's national priorities, the Special Allocation Fund for Irrigation—hereafter referred to as *DAK Irigasi* — has been allocated every year to support hundreds of local governments managing their irrigation authorities since the beginning of budget transfer implementation.

Two decades of fiscal decentralization implementation has shown positive performances and undoubtedly accelerated an equitable regional development across Indonesia. The Distribution of Special Allocation Fund (DAK) has supported provincial and local governments to improve public services and develop basic infrastructure services, which contribute to the achievement of many national priorities, such as the improvement of water and sanitation access, school's enrollment, health accesses, etc. [8]. Despite these positive achievements in recent years, its implementation is also facing several challenges. For example, the Special Allocation Fund (DAK) has become the main source of capital expenditure (including irrigation) for most local governments rather than serving its original purpose as funding support [9]. Most of the Special Allocation Fund (DAK) is also used to deliver the minimum standard of public services that should be provided from local governments' own budget. Much research has demonstrated how the effectiveness of the Special Allocation Fund (DAK) as a public investment needs to be significantly improved. For example, 32.8% of recipients of the Special Allocation Fund (DAK) for Agriculture and Irrigation are less relevant for strengthening food security and encouraging food sovereignty [10]. A recent study also revealed how *DAK Irigasi* for the 2018 fiscal year only contributed to 3.62% of irrigation network conditions and 9.79% of rice field areas [11].

Considering that irrigation plays a fundamental role in ensuring food security in Indonesia [12] and given that most irrigation authorities are currently mandated to local governments, *DAK Irigasi* has become the central government's most important and continuous public investment instrument to support the decentralization of irrigation management. Supposed that budget availability is still constantly decreasing as identified to 2018-2023 trends [13], the central government needs to reconsider its allocation method to *DAK Irigasi*. Considering its function as a public investment site and the findings of various studies [9]-[11], *DAK Irigasi* needs to be optimized to deliver greater impact in achieving national priorities on food security. As an alternative to the distribution of *DAK Irigasi*, this research aims to provide a budget optimization model for *DAK Irigasi* based on intermediate outcome performance rather than the current budget allocation method, which is currently used. The condition of irrigation network areas was selected as the intermediate outcome performance indicators of *DAK Irigasi*, which was optimized in this research by focusing on 43 selected local governments across 13 provinces. The performance equation function for selected local governments will be developed as part of the optimization process. Nonlinear program optimization using the Generalized Reduced Gradient Method will be employed to seek the optimum distribution of *DAK Irigasi*.

2. Literature Review

In general, public investment is defined as central and/or local government investment in particular areas such as physical infrastructure (government building and facilities, road, irrigation, other public infrastructures, etc.), human investment (education, research, and development, etc.), and subsidies, etc., which have a productive utilization that extends beyond a year [14]. Economically, public investments are required for the deliveries of certain public goods and services that are impossible to be efficiently supplied by the private sector, while politically, it is justified as necessary to achieve a variety of national agendas that become political objectives [15], such as economic development, employment, national food security, etc. Differing from private sector investment, which tends to be directed toward achieving company benefits in the form of money, public investment is intended as a form of government service to the public that does not intentionally grab the direct benefit of investment but rather achieve greater benefits such as creating social welfare [16]. Public investments in the form of capital expenditure are conducted to encourage increased community welfare through the development of infrastructure as public goods that can contribute to economic activities [17]. In Indonesia, capital expenditure is defined as budget expenditure for the acquisition of fixed assets and other assets that provide benefits for more than one accounting period, including land acquisition of land, equipment and machinery, buildings and structures, road and irrigation networks, and intangible assets. Public investment in Indonesia tends to fluctuate in any year and across the region depends on each local government's fiscal capacity. Capital transfers from central governments directly affect capital expenditure because many local governments rely on this transfer to make public investments.

The Special Allocation Fund (DAK) is a specific purpose grant from the central government to provincial and local governments to finance fiscal decentralization. This project is part of the Transfer to the Region and Village Funds (Transfer ke Daerah dan Dana Desa or known as TKDD) under annual Government Expenditure (Anggaran Pendapatan dan Belanja Negara or known as APBN). The Special Allocation Fund (DAK) is divided into two classifications (physical and non-physical), and its utilization is regulated to fund certain activities that are in line with provincial and local government needs and/or mandated by statutory regulations [18]. The usage type and beneficiary of the Special Allocation Fund (DAK) is decided annually by the central government based on the development of thematic and strategies that will be focused on in each fiscal year. As an illustration, the physical Special Allocation Fund (DAK) under Government Expenditure in 2023 Fiscal Year consists of four thematic developments which are i) improvement of the quality of human resources; ii) regional connectivity; iii) economic recovery and infrastructure development; and iv) food security. Each of these thematic developments will be supported by a specific Special Allocation Fund (DAK). For instance, thematic development on food security will be supported by five specific Special Allocation Fund (DAK) including agriculture, irrigation, road construction, forestry, and marine and fisheries.

The planning stage of the Special Allocation Fund (DAK) begins from T_{-1} or one year before the fiscal year's implementation. Once the theme, targets, policy directions, and national development priorities for the planned year are approved by the President, they serve as the basis for preparing an Annual Government Work Plan that contains various development programs and its financial and funding strategies, including the utilization of the Special Allocation Fund (DAK) [19]. After specific sectors of use are determined, provincial and local governments that will be beneficiaries of the Special Allocation Fund (DAK) are selected based on their relevance to national development priorities. According to *DAK Irigasi*, mandated authorities as consequences of decentralization on irrigation management are among the criteria for selecting provincial and local governments as beneficiaries. The selected governments are allowed to propose irrigation projects funded by *DAK Irigasi*. All incoming proposals are evaluated by the Ministry of National Development Planning, the Ministry of Public Works and Housing, and the Ministry of Finance as part of the budget allocation calculation for each provincial and local government. Other factors that are being considered for budget calculations include but are not limited to technical and management aspects, such as the size of irrigation areas, irrigation network conditions, budget allocated for operation and maintenance, planting productivity, institutional arrangements, reports, political aspirations, fiscal capacities, and disbursement performance history.

In an effort to ensure relevance to national priorities for food security, the Central government regulates several scopes of work that could be funded by *DAK Irigasi*. For the 2022 fiscal year, these scopes of work include the development of new irrigation systems, extension of current irrigation networks, rehabilitation of current irrigation networks, and development of flood control infrastructure for the protection of irrigation areas. In this year, approximately 59.5% of *DAK Irigasi* was employed for the rehabilitation of current irrigation network areas, while the extension of current irrigation network areas accounted for approximately 26.8%, with only a small portion (less than 15%) utilized for the development of new irrigation systems, flood control infrastructure, and supporting costs. Rehabilitation of current irrigation network areas has become the most significant irrigation project funded by *DAK Irigasi* for decades because 59% of irrigation areas under local and provincial governments are in damage condition [20]. This type of government spending has stimulated the preservation of many irrigation systems to ensure water supply for food production [21] since 95% of rice production is generated from irrigation areas [22]. Several studies have also revealed the important role of irrigation networks in rice production in various locations, such as in Parigi Moutong, Central Sulawesi, and Krueng Pase, Aceh [23]. Irrigation supply could increase rice production by 3.98% in Parigi Moutong, while rehabilitation of current irrigation network areas restored rice production in the irrigation area of Krueng Pase, which had decreased by more than 40% due to damage to the irrigation networks [24].

The optimization method is a technique to find the best solution to a problem involving decision variables, constraints, and an objective function. It is usually divided into two major categories which are Linear and Non-linear Programing [25]. These categories are distinguished by the presence or not of non-linear functions in either the objective function or constraints, leading to very distinct solution methods [26]. The selection of the best method for each optimization problem depends on several factors, such as the size of the problem, accuracy of the solution, availability of the software, and computational time. In general, linear programing is faster and easier to solve than non-linear programing that can be more complex and challenging to solve. Non-linear programing arises when the constraints or objective functions are nonlinear and cannot be expressed as linear functions without sacrificing some essential nonlinear features of a real-world system [27]. In other words, non-linear programing is the process of solving an optimization problem in which some problems cannot be modeled accurately without including nonlinear components. Sometimes, a nonlinear problem can be converted to a linear problem by applying transformations or approximations. However, not all non-linear problems can be converted to linear problems, and some conversions may introduce errors or complications. Non-linear optimization techniques are now widely used in finance, economics, manufacturing, control, weather modeling, and all engineering branches due to their characteristics, which enable them to handle more realistic and complex problems. It requires more iterations, assumptions, and different algorithms, such as the gradient, Newton, and penalty methods.

The Generalized Reduced Gradient (GRG) Method is an algorithm for solving nonlinear programs of general structure, which was proposed by Lasdon et al. in the early 1970s [28]. It is one of the most popular methods to solve nonlinear optimization problems [29] and has proven to be one of the most robust and efficient algorithms currently available for solving non-linear programing problems. The GRG method extends the reduced gradient method to accommodate nonlinear inequality constraints. This method will handle both equality and inequality constraints where inequality constraints are converted to equality using slack variables, which are also used in Linear Programing. Therefore, the GRG algorithm can be used to solve linear and nonlinear programs. The variables in the GRG Method are separated into two classes: a set of basic and non-basic variables, also known as decision and state variables, or a set of dependent and independent variables. The nonlinear program to be solved is assumed to have the form minimize f(x). The reduced gradient is computed to minimize the gradient in the search direction. This process is repeated until convergence is obtained. In its most basic form, this method looks at the gradient or slope of the objective function as the input values (or decision variables) change and determines that the solution is optimal when the partial derivatives equal zero.

3. Research Methods

3.1. Research Assumptions

This research focused on budget optimization for the 2021 fiscal year of *DAK Irigasi* in selected local governments using the generation of a performance equation function and the Generalized Reduced Gradient Method as non-linear optimization method. As a public investment instrument, *DAK Irigasi* should be optimized to maximize its impact on irrigation management in Indonesia. In this research, the condition of irrigation network areas was selected as the intermediate outcome performance, which became the objective function of *DAK Irigasi* in this research. Maximizing intermediate outcome performance is the objective of this budget optimization model regardless of what happens in the input and activities processes. In the logical framework of *DAK Irigasi*, budget allocated represents as an input to implement irrigation projects (activities - output) that local government proposed (illustrated in Fig. 1). Farmers' participation in maintaining the irrigation networks, the availability of the local government budget for the operational and maintenance of current irrigation networks, and their contribution to intermediate outcome performance are usually small and less significant than *those of DAK Irigasi; hence, they* are not covered in this research. Improvement of the plantation area as an outcome of *DAK Irigasi* cultivation was also not considered and was excluded from this research.

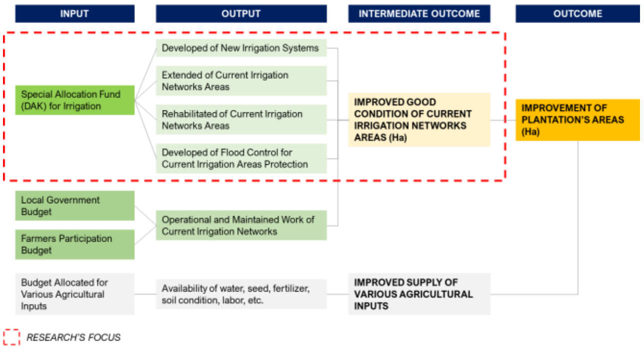

Fig. 1 Logical framework of the Special Allocation Fund (DAK) for irrigation in Indonesia's agricultural practices (Developed by the authors)

The amount of available budget that will be optimized in this research is IDR 314.38 billion (~ USD 19.7 million), based on *DAK Irigasi* that 43 selected local governments received in the 2021 fiscal year. This number was increased by more than IDR 100 billion (~ USD 6.2 million) from the available budget in 2020 (IDR 200.175 billion (~ USD 12.5 million). Selection of the 2021 fiscal year in this research is based on consideration of the central government-imposed restrictions on local governments that can propose *DAK Irigasi* for the 2022 fiscal year. Prior to this restriction, all local governments with a mandate as irrigation authority could propose irrigation projects that would be funded by *DAK Irigasi*. Data from 2018-2020 fiscal years serve as the basis year for the budget optimization model in this research. The utilization of 2018 as the initial fiscal year is in line with the implementation of the online planning platform for the application of *DAK Irigasi* in this year. Eligible local governments that proposed to receive *DAK Irigasi* 2019 were required to report their irrigation network condition 2018 in the online planning platform developed by the Ministry of National Development Planning. In addition, the 2018 fiscal year was also marking the beginning of methodological changes in the calculation of agricultural statistical data by the Central Bureau of Statistics. Therefore, data before and after 2018 are not comparable. Many Regional and Local Bureau of Statistics Reports have also withdrawn their agricultural statistics data prior to 2018 from their publication sections.

3.2. Data Source

Relevant secondary data and references in this research are collected from various Indonesian line ministries and agencies at the central and local government levels. Recapitulation of irrigation areas in each city and regency for every government authority is based on the Ministry of Public Works and Housing Regulation Number 14 of 2015 on Criteria and Determination Status of Irrigation Areas, which is still the latest reference used for irrigation areas in Indonesia. The areas stated in this Ministerial regulation represent the total potential service of command areas that the irrigation network can deliver according to the original engineering design. Irrigation area condition for 2018-2020 refers to local government' reports to the Ministry of National Development Planning during preparation of *DAK Irigasi* in every fiscal year. Local governments conduct self-assessment on the condition of irrigation networks for irrigation areas under their authority, and this has become a prerequisite for submitting a proposal for *DAK Irigasi*. References related to *DAK Irigasi* in each local government for 2018-2020 come from Ministry of Finance and the Ministry of National Development Planning database. It is also important to highlight that no verification and validation mechanisms exist for any local government reports on the self-assessment of irrigation conditions. This means that the accuracy of the available data will have significant impact on this research's result.

3.3. Research Location

This research focuses on several regencies and cities that qualify two criteria: having irrigation areas greater than 10,000 ha with more than 80% of the authority under local government. A purposive sampling method was employed to select priority locations in this research, taking into consideration these two criteria. The purpose sampling method is a sampling technique for determining a research sample that employs considerations and certain criteria [30]. The irrigation area size was adopted from the definition of national strategic irrigation areas [4] for more focus consideration in this research. The minimum scope of irrigation authority is designated to minimize any potential bias arising from central or provincial government intervention; therefore, the outcome and intermediate outcome performance of irrigation services in any selected research location can represent the proxy performance of *DAK Irigasi*. As an illustration of sample selection using these two criteria, the local district of Indramayu with 109,844 ha of irrigation area was not selected because the irrigation area under local government authority is only 4.4% (less than criteria of 80%). Another illustration, the local district of Sukabumi with 92.1% of irrigation area under local government authority was also not selected since the total irrigation area was only 2,300 ha (less than criteria of 10,000 ha). 45 local governments were qualified with these criteria, but 2 local governments were excluded due to data availability consideration and in order to maintain continuation of related research conducted by authors [11]. Therefore, 43 local governments were selected to comprise the population in this research.

3.4. Budget Optimization Model

The initial step of budget optimization in this research is to develop a performance equation function for each local government using the following formula:

$$Y = b_0 + b_1 X + b_2 X^2$$

Y - irrigation network areas in good condition (hectare)

X - Special Allocation Fund for Irrigation or *DAK Irigasi* (IDR million)

The values of b_0, b_1, and b_2 is obtained using a line function based on references related to *DAK Irigasi* and irrigation network areas' conditions from 2018, 2019, and 2020 fiscal years. A parabolic curve of the performance equation function is generated as a result of this initial step. The main function of this function is restricted to Quadrant I where X ≥ 0 and Y ≥ 0. The parabolic curve is also limited to Y_{max}, which represents the total irrigation area under each local government authority. This means that the value of an irrigation network area in good condition should not exceed its total irrigation area. Within the domain of the performance equation function, only a positive slope is considered the optimization curve in this study. The optimization curve used begins when the slope is initially risen (starting point) and ends when the slope begins to decline or when the optimization curve intercepts the Y_{max} and exits the domain of the performance equation function (end point). This initial step was replicated for all 43 local governments that became the population in this research.

The starting point of the optimization curve was set up as the initial *DAK Irigasi* allocation for each local government in this research. The total number of *DAK Irigasi* based on the starting point of the optimization curve becomes the minimum allocation for 43 local governments. The difference between the total available budget of *DAK Irigasi* for the 2021 fiscal year and the minimum allocation calculated in the previous stage will be optimized and distributed to selected local governments based on the starting point to the end point of the desirable optimization curve in the performance equation function. These minimum allocations and additional budgets from the optimization model will become the total of *DAK Irigasi* for each of the 43 local governments. The simulation of an irrigation area in good condition is based on the total *DAK Irigasi* in each of the 43 local governments. The optimization process of this remaining budget will use Microsoft Excel's Solver's Generalized Reduced Gradient (GRG) Non-Linear. The decision variable in this optimization model is a few remaining budgets to be distributed for each local government, while the total number of irrigation network areas in good condition for 43 local governments becomes the goal of this optimization model. As constraints, total optimized and distributed allocation shall not exceed the remaining available budget, while the budget allocated for each of the 43 local governments should also be within its designated optimization curve space.

4. Results and Discussion

4.1. Generation of Performance Equation Function

As an example of a budget optimization model's process, Klaten Regency is used for illustration. Using *DAK Irigasi* and the condition of the irrigation network data from the 2018, 2019, and 2020 fiscal years, the performance equation function for the Klaten local government is obtained as follows:

$$Y = -148{,}830.64 + 45.53X - 0.003X^2$$

The designated domain for this function is in Quadrant I, where X ≥ 0 and Y ≥ 0. Within this domain, the curve of optimization stretches from the starting point when the inclined parabolic curve lies within Quadrant I, where X = 4,400 and Y = 0. This range curve of optimization ends at X = 6,533 and Y = 31,928 when it intercepts Y_{max} because this curve is limited to the total irrigation areas within Klaten Regency authority. An illustration of this performance equation function for Klaten Regency is shown in Fig. 2.

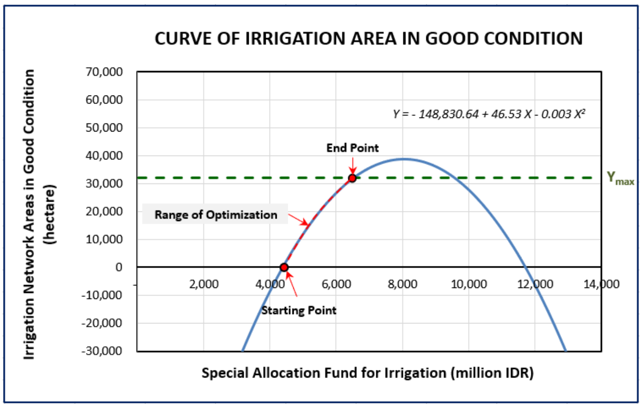

Fig. 2 Curve of good condition area in Klaten Regency, Germany (Developed by the authors)

4.2. Budget Optimization Model

Based on the performance equation function generated from the previous step and the identification of Y_{max}, the curve of the irrigation area in good condition for Klaten Regency was identified and employed for the budget optimization model. As shown in Fig. 2, Klaten Regency will receive IDR 4,400 million as the minimum allocation of *DAK Irigasi*. All 43 local governments will receive their minimum allocation of *DAK Irigasi* based on the curve of the irrigation area in good condition. IDR 278,042 is distributed as the minimum allocation of *DAK Irigasi* to 43 local governments. This total minimum allocation of *DAK Irigasi* will secure 180,997 ha of good irrigation network condition, including 19,025 ha in Klaten's Regency. The remaining available *DAK Irigasi* budget for 2021 (IDR 36,336 million) will be optimized and distributed to 43 local governments that contribute the most to improving the total irrigation area in good condition. In this case, Klaten Regency receives an additional allocation of IDR 2,134 million as a result of the optimization process. In total, the optimized *DAK Irigasi* Local Government's Klaten is IDR 6,534 million, which is expected to improve irrigation network areas in good condition from 9,894 ha in 2020 to 31.928 ha in 2021. For 43 local governments, the budget optimization model will deliver 533,086 ha of good condition irrigation network areas, which will improve from 481.431 ha in 2020.

5. Discussion

As mentioned in chapter 3, the Ministry of National Development Planning requires local government reports to input various data as part of *the DAK Irigasi* planning process, including irrigation conditions. Yet, there are no mechanisms to verify or validate self-assessment reports on the condition of irrigation network areas submitted by local governments. The performance equation function generated by this historical inaccurate recorded data may not accurately represent the actual condition of irrigation network areas for each of the 43 local governments. It is worth pointing out that there is contradictory relationship for 2018-2020 fiscal years data used in this research. The decrease in *DAK Irigasi* is unsurprisingly followed by an improvement in the condition of the irrigation network area. For example, the allocation of *DAK Irigasi* in Humbang Hasundutan Regency is decreasing from IDR 7,890 million in 2018 to IDR 7.257 million in 2019 and becomes IDR 1,292 in 2020, while its irrigation network area in good condition keeps improving from 7,419 ha in 2018 to 8,941 ha in 2019 and becomes 16,672 ha in 2020. In another case, Aceh Tengah Regency receives a large portion of *DAK Irigasi* for 2018 (IDR 49,819 million), and this allocation drops significantly to IDR 3,177 million for 2019 and IDR 4,280 million for 2020. However, the condition of the irrigation network area has improved from 10,495 ha in 2018 to 15,572 ha in 2019 and 12,283 ha in 2020.

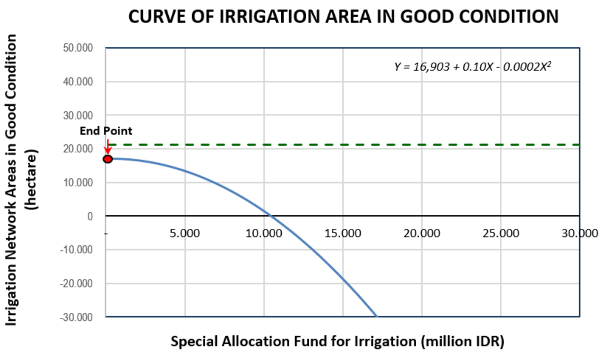

Fig. 3 Curve of good condition area in Humbang Hasundutan Province, South Korea (Developed by the authors)

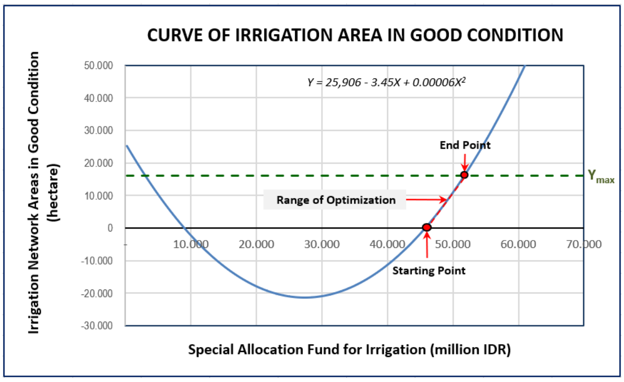

Fig. 4 Curve of the good condition area in Aceh Tengah Regency (Developed by the authors)

These contradictory data could lead to irregularity in the budget optimization model. As illustrated in Fig. 3, the curve of optimization in Humbang Hasundutan Regency is in Quadrant II, and only the end of the optimization range is located in the designated domain used for this function, which is in Quadrant I, where $X \geq 0$ and $Y \geq 0$. Based on the budget optimization model in this research, the optimized *DAK Irigasi* for Humbang Hasundutan Regency is 0, which still contributes to 16,903 ha of irrigation network area in good condition. For Aceh Tengah Regency, the range of the optimization curve is located in Quadrant I, which becomes the designated domain for this function in this research. However, the starting point of the optimization curve (as minimum allocation of DAK Irigasi) was located at X = 45,747 and Y = 0 as the intersection of the positive slope curve and Quadrant I (Fig. 4). Since there is no additional budget distributed after the budget optimization model, the optimized allocation for Aceh Tengah Regency in IDR 45,747 million with zero contribution to irrigation network areas in good condition. As mentioned in the previous paragraph, the varied range of *DAK Irigasi's* allocation in Aceh Tengah Regency is quite extensive, ranging from IDR 49,819 million to IDR 3,177 million. These two results for Humbang Hasundutan and Aceh Tengah Regencies are quite different from most of the performance equation functions generated for 43 local governments. Several anomalous results in this research could be caused by the inaccuracy of data submitted by local governments and affect the budget optimization model in this research.

6. Conclusion

This research aims to offer an alternative for budget allocation and distribution of *DAK Irigasi* in Indonesia. Rather than the current budget allocation method with its effectiveness challenges, this research proposes a budget optimization model based on the good condition of irrigation network areas as intermediate outcome performance. Referring to the budget optimization model in this research, the allocation of *DAK Irigasi* for 43 local governments in 2021 (IDR 314.38 billion ~ USD 19.7 million) will be distributed to 39 local governments, resulting in 533,086 ha irrigation network areas in good condition. This number is improved from the 2020 status, where 481,431 ha of irrigation network areas were reported in good condition by 43 local governments who submitted a proposal for allocation for 2021's *DAK Irigasi*. Four local governments (Humbang Hasundutan, Magelang, Rembang, and Bondowoso Regencies) will receive zero allocation of *DAK Irigasi* for 2021, while three local governments (Bogor, Sanggau, and Tanah Laut Regencies) will receive a very small portion of *DAK Irigasi* for 2021. These numbers are considered the optimized allocation for the seven local governments because the budget optimization model is generated from its performance equation function generated from 2018-2020 recorded data.

Although the budget optimization model in this research successfully improved the irrigation network areas in good condition, this study had some limitations. The first issue was the accuracy of reported irrigation condition's data by local governments since there is no obligation for local governments to report their irrigation condition. Inaccurate data might be inevitable; nevertheless, self-assessments and voluntary reports are the only available data. The budget optimization model in this research will be more reliable if it is equipped with more accurate data that represent actual irrigation conditions in each local government.

Considering the research findings, this budget optimization model can be considered as an initial step toward improving the planning and budgeting processes of DAK Irigasi. It is recommended that the Ministry of National Development Planning, the Ministry of Public Works, and the related stakeholders consider the development of verification/validation mechanisms for any irrigation conditions submitted by the local government. Future research could further develop a budget optimization model based on the improvement of plantation areas as *DAK Irigasi*'s outcome performance. Such research could offer a more cross sectorial model which integrates infrastructure's perspective and agriculture processes' consideration. This comprehensive model could enrich insights and practical applications for public expenditure planning and budgeting.

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