Irrigation Channel Development and Rejuvenation to Support Sustainable Agricultural Cultivation Systems in Indonesia

Ali Jamil[1], M. Saleh Ali[1], D. Salman[1], I. M. Fahmid[1], R. A. Chairunnisya[2]

[1]*Department pf Development Studies, Hasanuddin University, Makassar, 90245, Indonesia*
E-mail: alijamil1611@gmail.com

2Directorate General of Agricultural Infrastructure and Facilitie, Jakarta, 12540, Indonesia

Abstract— **Sustainable agriculture is a vital indicator of progress toward the SDGs (SDGs) and acknowledged as the government's top priority for meeting national food needs. One of the parameters for sustainable agriculture is water availability for agricultural lands. The development and rejuvenation of irrigation networks is a program to support the achievement of sustainable food in Indonesia. This program includes irrigation networks rehabilitation (INR), development of water sources, and conservation actions in anticipation of climate change. The paper aims is to examine the effectiveness of irrigation network development and rejuvenation in supporting agricultural land productivity and water availability to ensure sustainable agriculture. Data collected from The Directorate of Agricultural Infrastructure and Facilities, the Ministry of Public Works and Public Housing, and the Central Statistics Agency provided data. Data analysis revealed that an increase in INR had a linear relationship with rice productivity. Java Island is still the focus of INR's activities, with a distribution percentage of 32.71%, followed by Sumatra (30.42%), Sulawesi (20.36%), Kalimantan (6.80%), Bali and Nusa Tenggara (8 .37%), and Maluku and Papua (1.44%). The level of fulfilment of irrigation for agricultural land in Indonesia is 83%. This show that the development and maintenance of irrigation networks are still needed. Piped/pumping irrigation water sources began in 2016 (1542 units), representing 28.25 per cent of the target in 2019 (5441 units). The construction of reservoirs and long-storage aims to ensure the availability of water. In 2016, they were massively built (1907 units), then dramatically decreased in the following year (490 units), and became relatively stable from 2018 to 2021. Water availability for agricultural land increases as water resource development and conservation measures improve, and it has a positive correlation with rice production. Implementation of irrigation network development and rejuvenation activities can support rice productivity. It also contributes to achieving sustainable agriculture indonesia.**

Keywords— **Irrigation; productivity; sustainable agriculture; water resources**

I. INTRODUCTION

According to Law No. 22 of 2019, the sustainable agricultural cultivation system remains the government's top priority in achieving sustainable food. Sustainable agriculture is a critical component of achieving the Sustainable Development Goals (SDGs). The concept of sustainability is built on three interconnected pillars: planet, people, and profit. The concept of Good Agricultural Practice (GAP) manifests the three main pillars in the agricultural sector. The availability of agricultural infrastructure, precisely water sources on agricultural lands, is one of the parameters observed to assess the success of achieving sustainable agriculture.

Various efforts have been made to optimize water use to meet the water supply of agricultural land to realize the cropping index and agricultural production. Both are food fulfilment functions. The population of Indonesia in 2021 is expected to be 273.87 million people, with a projected increase to 300 million people by 2030. The increase in population is inversely proportional to the increase in demand for agricultural food consumption. To meet agricultural food consumption needs, assuming a per capita consumption of 1,551 kg/week, at least 15 million hectares of total planted area are required.

The previous Government frequently faced some challenges when implementing programs to improve food security: the occurrence of damage to irrigation network infrastructure. Natural disasters cause damage to irrigation infrastructure, as does less-than-optimal irrigation management. These are the results of ineffective operation and maintenance (OM) activities. The implication is that the irrigation network's damage is worsening, causing the irrigation system's performance to deteriorate.

During President Jokowi's presidency, fulfilling food needs through development programs and accelerating infrastructure became top priorities. It is clear from the first task of the Government's 2022 Work Plan, which is to accelerate and continue infrastructure development, including the construction and development of agricultural infrastructure and facilities. As a result, the Ministry of Agriculture establishes a program for providing land and water infrastructure as a strategic activity for agricultural infrastructure and facilities through the Directorate General of Infrastructure and Facilities. This program is divided into two sections: irrigation network development and rejuvenation, including irrigation network rehabilitation, water source/ pump development, dam construction, and piped irrigation.

Thus, irrigation plays a vital role as a significant component and supporter of sustainable agricultural cultivation. This paper discusses the significance of the irrigation network development and rejuvenation program in Indonesia on the production and productivity of food crops, especially rice, to support sustainable agriculture.

II. LITERATURE STUDI

A. Sustainable Agriculture Concept

The term "*sustainable agriculture*" was developed in the 1960s in response to environmental degradation caused by synthetic fertilizers and pesticides on agricultural land [1], as

described in Rachel Carson's book Silent Spring. According to [2] in their paper that the concept of sustainable agriclture is depicted as an ideal goal that must be attained and can be viewed from various perspectives. This concept is dynamic and complex, and its implementation is constantly being revised. In the current millennium, sustainable agriculture is defined as a "*multifunctional*" agricultural activity that functions as a producer of food and agricultural products and agricultural activities carried out with due regard for environmental objectives to preserve the ecosystem's functions/services.

As in [3], sustainable agriculture is a concept that maintains a balance of three major components: environmental aspects, economic aspects, and social aspects of the agricultural sector. Through various models and approaches, sustainable agriculture aims to increase food production and community welfare while maintaining environmental quality [4].

After various environmental damage and a decline in food production due to the Green Revolution, the concept of sustainable agriculture began to be introduced in Indonesia. Since then, as part of the implementation of sustainable development, Indonesia's agricultural development has been directed toward sustainable agricultural development [5]. The government prioritizes sustainable agriculture as a priority activity to achieve food security through the Ministry of Agriculture and various work programs. Implementation of the program includes the development and revitalization of irrigation networks, the development of food estates, the protection of agricultural land from land conversion, the provision of subsidized fertilizers (both synthetic and organic), and the facilitation of agricultural tools and machinery.

B. Irrigation Channel Development and Rejuvenation

Agricultural irrigation is one of the most influential aspects of distributing water into the agricultural system. Water distribution requires the development and revitalization of irrigation networks [6]. A strategic program of activities is supporting the irrigation network development and rejuvenation program, which includes: (i) irrigation network rehabilitation; (ii) development of water sources/pumps; (iii) reservoir construction; and (iv) piped irrigation development..

1) Irrigation Network Rehabilitation

Irrigation network construction is intended for agricultural cultivation activities. Irrigation networks can be damaged due to the building's age, heavy rainfall, channel leakage, silt, and garbage (Midyanti, 2019). Irrigation networks that have been damaged must be repaired so that irrigation functions and services can resume as before. As in [7] research on irrigation networks in Padangkeling reveals that the area's irrigation networks are in qualitatively 'bad' condition, with a 'severely damaged' level of damage. In terms of quantitative performance, the Padangkeling irrigation network has a performance index of 16.68 per cent, less than 40 per cent. This condition indicates that the irrigation network in the area requires periodic restoration, i.e., heavy asset repair and replacement. The rehabilitation of irrigation networks exemplifies the value of sustainable development, namely achieving food security and supporting sustainable agriculture.

2) Development of water sources/pumps

According to the Directorate General of Agricultural Infrastructure and Facilities Decree No. 06/Kpts/SR. 120/B/01/2022 regarding technical guidelines for developing pumped irrigation for the fiscal year 2022, water availability is an essential factor in cultivation practices. This requirement is met by rainwater and irrigation networks. However, in certain circumstances and locations, the amount of rainwater cannot meet water needs, and the location is outside the irrigation system. Water distribution management is required to meet the water requirements of plants. Water sources are being developed, particularly on lands outside the irrigation system, through technical irrigation (pumping). Rivers, lakes, and other bodies of water provide water. Pump irrigation systems are used on dry land and various technologies to lift and drain water from water sources to agricultural lands.

In order to apply GAP values, according to [8] who conducted research on shallot cultivation land in Bantul using a solar pump irrigation system (SPIS). The solar pump irrigation system is more environmentally friendly because it does not use fossil fuels, has a low carbon footprint, and is said to use water and energy efficiently. The results also revealed that the use of SPIS improved shallot growth and production when compared to conventional irrigation. Furthermore, SI-PTS is much more cost-effective, resulting in significant savings.

3) Development of retention basin and long storage

Climate change has the most significant impact on the agricultural sector. The basin and long-term storage development program is a form of anticipating and adapting to climate change. The goal of creating a retention basin and long storage is to collect rainwater and use surface water. Retention basin development is an effort to conserve water in an efficient, economical, and site-specific manner and regulate water availability to meet farm water needs [9]. According to [10], basin development in the Tumenggung Regency had a significant impact on overcoming drought, increasing agricultural production, and increasing farmers' income and welfare.

4) Piping irrigation development

The goal of piped irrigation development is to increase water availability on agricultural land that a technical irrigation system does not serve. The Directorate General of Agricultural Infrastructure and Facilities develops water sources through piped irrigation activities through the Directorate of Agricultural Irrigation [11]. According to [12], the water source in dryland is typically located lower than the irrigation target area. A pump must exploit the potential of water, which is then channelled through open or closed channels (privatization). Piped irrigation effectively provides plants with the water they require; however, planning and financing must also be carefully considered when constructing a piped irrigation system.

III. THE MATERIAL AND METHODE

A. Data Collection

Data on the number of rehabilitation of irrigation networks, pumped irrigation, piped irrigation, and reservoirs were obtained from the Directorate of Agricultural Irrigation and the Directorate General of Infrastructure and Facilities. Rice production data obtained from the Central Statistics Agency (CSA).

B. Data Processing

The data obtained is then processed and presented in graphical form using Origin Pro 2016 and Microsoft Excel 2021.

C. Agricultural Land Irrigation Fulfillment Rate

The level of fulfilment of irrigation for agricultural land is calculated using equation 1.

$$\left(\frac{a}{b}\right)\times 100\% \qquad (1)$$

Note:

a: Identification of total agricultural land supplied with water via irrigation networks, either through rehabilitation of irrigation networks, development of water sources, or development of agricultural reservoirs (ha); and

b: Identification of total irrigation needs based on the agricultural land area (ha).

IV. RESULT AND DISCUSSION

A. Irrigation Network Rehabilitation and Rice Productivity

Irrigation Network Rehabilitation (INR) is an activity that involves repairing or improving irrigation networks in order to restore or improve irrigation functions and services in order to increase planting area and cropping intensity. The Directorate General of Agricultural Infrastructure and Facilities also sustainably and equitably supports INR's activities. Figure 1 depicts the number of INRs that have been implemented between 2015 and 2022.

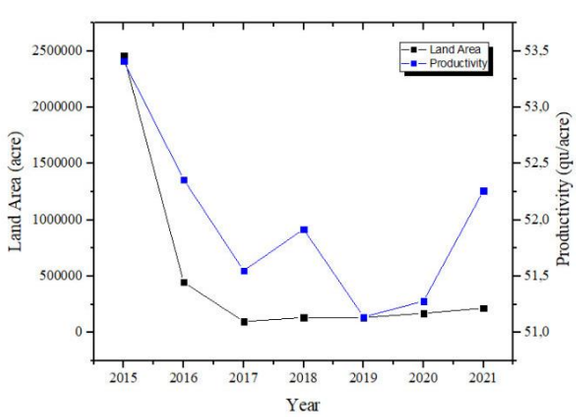


Fig. 1 Agricultural irrigation network rehabilitation and paddy productivity 2015-2021

Figure 1 depicts the government's priority in putting the INR program into action. This activity is a priority program for which the government has allocated a state budget. As a result, INR's land area increased significantly compared to previous years. These are a progression and realization of the 3 million hectare Nawa Cita program for INR. Furthermore, the extent of network rehabilitation has an impact on rice productivity. INR activities follow a similar pattern as rice productivity, with an increase in INR area followed by rice productivity. This is consistent with [13] findings in her study, which discovered that INR positively impacted rice production and productivity. Even though it does not affect cropping patterns, the better the irrigation network, the fewer production inputs are used, and rice production increases. A sharp decline occurred in 2016 (82%), and the value became more stable the following year. The parameters of rice productivity have also decreased. One of the reasons for the decrease in state budget allocation for the INR program was a shift in the ministry of agriculture's focus to other infrastructure and facilities programs. This condition undoubtedly has an impact on rice productivity.

As shown in Figure 2, Java remains the government's top priority in terms of improving and maintaining agricultural infrastructure when implementing INR. Java is the largest INR area, accounting for 32.84 per cent of the total area, followed by Sumatra (30.42 per cent), Sulawesi, Kalimantan, Bali, Nusa Tenggara, and Papua.

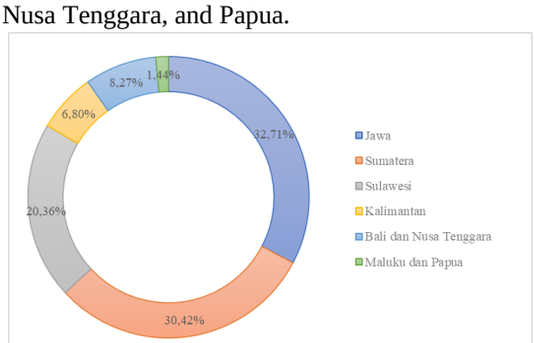
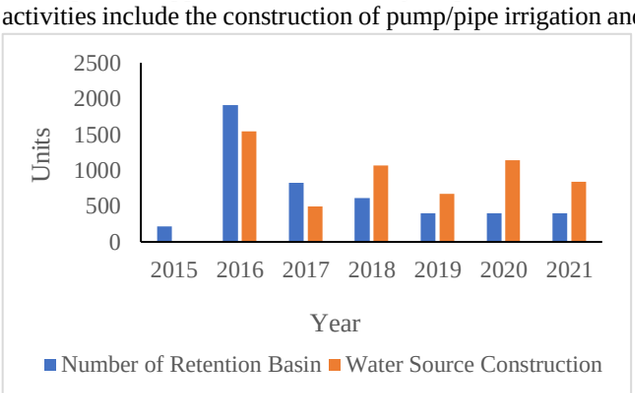


Fig. 2 Area of irrigation network rehabilitation activities per area 2015-2019 (Source: Directorate General of Agricultural Infrastructure and Facilities, 2021).

This is understandable considering that most of the agricultural land is located on the island of Java and is also a food barn for the people of Indonesia. Based on [14] data, rice production in Java reached 5,474,057.49 tons per hectare or equivalent to 52.58% of the total rice production in Indonesia.

B. Water Resources Development

Water source development occurs in agricultural cultivation areas with insufficient water availability for plant needs. Water source infrastructure and facilities must be developed to support the sustainability of production. These activities include the construction of pump/pipe irrigation and



retention basin/long storage. Figure 3 depicts data on the development of water sources from 2015 to 2021.

Fig. 3 Water resource development 2015-2021
(Source: Annual Report of Directorate General of Infrastructure and Facilities 2019-2021).

Figure 3 shows that the construction of water sources began to be built in 2016, where this year massive water sources were built, amounting to 1542 units. In the following years, the number of water source buildings fluctuated, and the development of water sources was not as much as in 2016. The same pattern was also found in constructing reservoirs as water storage facilities. Increasing the availability of water sources is expected to support sustainable agricultural development and food security. As in [15], in their article, explained that the Ministry of Agriculture, together with the Ministry of Public Works and Public Housing, had built a lot of agricultural infrastructures that support the availability of water sources in the 2015-2019 period. Water availability on agricultural land can extend the planting period or increase the cropping index (CI) and agricultural extensification.

C. Agricultural Land Irrigation Fulfillment Rate

Increased availability, access, and consumption of quality food are one of the performance indicators of agricultural infrastructure fulfilment. land, irrigation, and drainage networks and access to financing and protection for agricultural businesses are all part of the infrastructure. Calculation based on Eq. 1 is used to assess the increase in irrigation of agricultural land. Figure 4 depicts the agricultural land irrigation fulfilment rate.

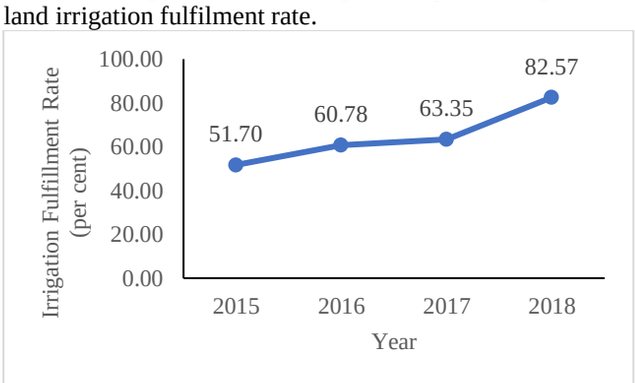


Fig. 4 Agricultural land irrigation fulfilment rate 2015-2018

From 2015 to 2018, there was an increasing trend of irrigation for agricultural land in Indonesia. Until 2018, the irrigation rate for irrigated rice fields in Indonesia has reached 83%. This figure shows the improvement and actualization of the government's focus on improving the management of Indonesia's abundant water resources for the agricultural sector. Management of water resources, through rehabilitation of irrigation networks, development of piped/pumped irrigation, construction of dams and long storage for irrigating agricultural land, is essential to optimize it to achieve food security [16].

CONCLUSION

Management of water resources for agricultural needs is vital to support the production and productivity of food crops. Through the directorate general of agricultural infrastructure and facilities, the government has launched various programs with a focus on improving agricultural infrastructure. Program implementation involves rehabilitation of irrigation networks, development of piped/pumping irrigation, construction of water source buildings, and construction of dams. From 2015-to 2021, the percentage of irrigation network rehabilitation was centred on Java (32.71%), followed by Sumatra, Sulawesi, Kalimantan, Bali and Nusa Tenggara, Maluku, and Papua. Massive construction of water sources and reservoirs was built in 2016, then declined and fluctuated in the following years. The irrigation rate of irrigated rice fields in Indonesia reaches 83%. Water availability on agricultural land is directly proportional to rice productivity and cropping index. This increase supports food security and sustainable agriculture.

ACKNOWLEDGMENT

We would like to thank the Ministry of Agriculture, the Directorate General of Agricultural Infrastructure and Facilities, the Central Statistics Agency, and those who contributed to this study..

REFERENCES

[1] Rose D.C., W. J. Shutterland, A. P. Barnes, et al. "Integrated farm management for sustainable agriculture: Lessons for knowledge exchange and policy." *Land Use Policy*., vol. 81, pp: 834-842. 2019.

[2] J. Velten, J. Leventon, N. Jager, and J. Newig. "What is sustainable agriculture? A systematic review." *Sustainability*., vol 7. pp: 7833-7865. 2015.

[3] Garibaldi, L. A., G. Herren, B. D'Annolfo, et al. "Farming approaches for greater biodiversity, livelihoods, and food security." *Trends in ecology & evolution*., vol. 32. pp: 68-80. 2017.

[4] Talukder, B., and M. Saifuzzaman. "Sustainability of agricultural systems in the coastal zone of Bangladesh." *Renewable Agriculture and Food Systems*., vol. 31.2. pp: 148-165. 2016.

[5] Lagiman. "Pertanian berkelanjutan: untuk kedaulatan pangan dan kesejahteraan petani." In *Proc. National Conference in UPN 'Veteran' Yogyakarta*, 2021, paper 21.10.1, p.365-381.

[6] Directorate General of Agricultural Infrastructure and Facilities, "2021 Annual Report," annual report, Directorate General of Agricultural Infrastructure and Facilities, Ministry of Agriculture, Indonesia, 2021.

[7] Purbawa, G. B., N. P. Pandawani, I. G. N. A. Wiswasta, and N. U. Vipriyanti. "Analisis kinerja jaringan irigasi daerah irigasi padangkeling berbasis epaksi di Kabupaten Buleleng." *Jurnal ENMAP*., vol. 3. pp: 1-9. 2022.

[8] Rejekiningrum, P., dan Kartiwa, B. "Development of solar water pump irrigation system for water and energy efficiency in anticipation of climate change in bantul district, Daerah Istimewa Yogyakarta." *Jurnal Tanah dan Iklim*., vol. 41. pp: 159-171.2017.

[9] Decree of the Directorate General of Agricultural Infrastructure and Facilities No. 19/KPTS/SR 110/B/01/2021. Directorate General of Agricultural Infrastructure and Facilities, Ministry of Agriculture, Indonesia. 2021.

[10] Saputra, K. G. D., and D. G. Manar. "Manajemen pemerintahan Kabupaten Temanggung dalam upaya mengatasi kekeringan (studi tentang program pembangunan embung di Desa Ngropoh Kecamatan Kranggan, Kabupaten Temanggung)." *Journal of Politic and Government Studies*., vol. 9. pp: 31-40. 2020.

[11] Decree of the Directorate General of Agricultural Infrastructure and Facilities No. 06/KPTS/SR 210/01/2021. Directorate General of Agricultural Infrastructure and Facilities, Ministry of Agriculture, Indonesia. 2021.

[12] Fajar, A., M. Yanuar, J. Purwanto, and S. D. Tarigan. "Efficiency of pipe irrigation system to identify the feasibility of water supply in irrigation water management." *Jurnal Irigasi*., vol. 11. pp: 33-42.

[13] Evariani, E. "Analisis dampak rehabilitasi jaringan irigasi tersier terhadap pendapatan petani di Kabupaten Aceh Besar." *Agrifo: Jurnal Agribisnis Universitas Malikussaleh*., vol. 3. pp: 55-63. 2018.

[14] (2022) Central Bureau of Statistics website. [Online]. Available: https://www.bps.go.id/subject/53/tanamanpangan.html#subjekViewTab3

[15] Sutrisno N., and A. Hamdani. "Optimizing the Utilization of Water Resources to Improve Agricultural Production." *Jurnal Sumberdaya Lahan*., vol. 13. pp: 73-88. 2019.

[16] Sutrisno N., and N. Heryani. "The development of water saving irrigation to increase agricultural production of dry land and dry climates." *Jurnal Sumberdaya Lahan*., vol. 13. pp: 17-26.2019.