Analysis of irrigation network condition On Cipamarangan Irrigation system, Sukabumi Regency

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Abstract. Irrigation networks have important role to support agricultural productivity and farmers welfare. The decline in the condition and function of irrigation networks can lead to disruption in the distribution of water in irrigation areas. This occurs due to several things such as sedimentation, weed growth, corrosion of the floodgates and leaks in the channel walls. This study aims to evaluate the physical condition and functioning of irrigation networks based on field surveys and available technical data. The method used in this research is by identifying the condition and functioning based on indicators of structures, floodgates and measuring buildings. Assessment of the condition and functioning of each irrigation asset according to Peraturan Menteri Pekerjaan Umum dan Pe- rumahan Rakyat (PUPR) of 2015 and Kriteria Perencanaan Bagian Bangunan of 2013. The results showed that the condition of the Cipamarangan irrigation network was classified as not good with an index of 1.5 and its functioning was classified as not functioning with a percentage of 31%. Recommended actions are suggested to do heavy repairs or replacements on the irrigation network DI. Cipamarangan. In addition, the implementation of monitoring technology and community in- volvement in maintenance were identified as important steps to ensure the sustainability and opti- mization of irrigation networks.

1 Introduction

1.1 Background

Water is a basic need for humans to live life and improve the quality of life. Development in water resources aims to ensure that all people have equitable access to water, so that they can live healthy, clean and productive lives. In addition, development in the field of water resources aims to ensure sustainable water availability, increase resilience to climate change, and support food and energy security. The obstacles faced in irrigation management are the declining condition and func- tion of the irrigation network [1]. Irrigation is defined as an effort to bring water from its source for agricultural purposes, drain and distribute water regularly, and discharge it back through the waster after use [2,3]. The purpose of irrigation is to meet the water needs for agriculture, including soil wetting, fertilization, soil

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temperature regulation, and avoiding pest problems in the soil and others [4–6]. The irrigation network consists of a system of canals, buildings, and complementary buildings that are interconnected and needed for irrigation water management, starting from the provision, collection, division, provision, use, to disposal [7,8]. Irrigation networks in agriculture are divided into three types, namely Technical, Semi Technical and Simple Irrigation [9,10]. Measurement of the area of DI. Cipamarangan experienced differences, where the initial area of 614 Ha while the latest measurement results amounted to 223,81 Ha. The decline in the condition and function of irrigation networks occurs due to irrigation management that is no longer optimal in supporting the smooth distribution of water from the weir building to the dividing building, and then to the rice fields. This is caused by lack of maintenance, damage due to human actions and natural disasters, delays in repairing or maintaining irrigation networks, old irrigation age, and limited maintenance funds and other factors. In Peraturan Pemerintah Republik Indonesia No. 20 of 2006 about irrigation, ex- plained that irrigation network repair is an activity to restore its function and service as before. Alt- hough an irrigation network is well managed through operations and maintenance, it will eventually reach the limit of its service life. The length of the service life of an irrigation network is influenced by the condition of the water source, the type of construction (permanent, semi-permanent, or simple), the implementation of operations and maintenance, and natural conditions [11]. The effects of irrigation network damage can be both direct and indirect. Direct effects include reduced production capacity, reduced crop quality, and increased risk for farmers. Whereas indirect effects involve a decrease in the responsibility of farmers in maintaining the ecosystem of rice fields, because poor irrigation performance causes rice fields to become less supportive and useful for rice farming [12].

1.2 Research Problem Limitation

The problem limitations in this research are as follows:

- The research was conducted in Cipamarangan Irrigation Area, Surade Sub-district, Suka- bumi Regency.
- The research focuses on the physical condition of the building and main canal

1.3 Problem Formulation

Based on the background above, we can formulate the following problems:

- What is the physical condition of the building and main canal DI. Cipamarangan?
- What recommendations or actions are needed for the physical condition of buildings and main canals DI. Cipamarangan?

1.4 Research Objectives

The objectives of this research are as follows:

- To determine and determine the quality level of the physical condition of the building and main canal DI. Cipamarangan.
- To find out the recommendations or actions needed to improve the physical condition of buildings and main canals DI. Cipamarangan

2 Literature Review

2.1 Irrigation Network Performance Assessment

Irrigation Network Performance Assessment is an evaluation process carried out to assess the effectiveness and efficiency of an irrigation system in distributing water to agricultural land. This assessment includes several aspects, such as the physical condition of the irrigation network, the ability of the network to distribute water as needed, as well as the level of maintenance and operations carried out. A good performance assessment will help in planning improvements and management of irrigation networks to be more optimal [13].

- Condition of irrigation components
  Damage to the condition of irrigation components refers to damage or degradation of the function of parts of the irrigation system that affect the efficiency and effectiveness of irrigation. The percentage of damage to irrigation assets is divided into four damage criteria, namely:
  - The condition is declared good if the level of damage is less than 10% of the initial condition of the building or canal;
  - The condition is declared lightly damaged if the level of damage is between 10% and 20% of the initial condition of the building or canal;
  - The condition is declared moderately damaged if the level of damage is between 21% and 40% of the initial condition of the building or canal;
  - The condition is declared severely damaged if the level of damage is more than 40% of the initial condition of the building or canal.

The condition of irrigation asset components can be divided into structures, floodgates and measuring buildings [14–17]. Indicators of the condition of structures, sluice gates and measuring buildings are shown in Table 1, Table 2, Table 3 [18].

- Structure

Table 1. Structure Condition Indicators

Score	Condition	Indicator
4	Good	Damage to the structure of irrigation assets cracked and chipped
3	Lightly Damaged	Damage to irrigation assets with holes <0.40m
2	Medium Damaged	Damage to the structure of irrigation assets with holes >0.40m
1	Heavy Damage	Damage to the structure of irrigation assets collapsed

Source : Permen PUPR No. 12, 2015

- Water Gate

Table 2. Indicators of Water Gate Condition

Score	Condition	Indicator
4	Good	No damage
3	Lightly Damaged	There is damage to 2 parameters
2	Medium Damaged	There is damage to 3 parameters
1	Heavy Damage	There is damage to all parameters

Source : Permen PUPR No. 12, 2015

The parameters used are (1) Rusting, (2) Water gate support, (3) Door drive system, and (4) Door leaf.

- Measurement Builing

Table 3. Indicators of Measuring Building Condition

Score	Condition	Indicator
4	Good	No damage
3	Lightly Damaged	There is damage to 2 parameters

Score	Condition	Indicator
2	Medium Damaged	There is damage to 3 parameters
1	Heavy Damage	There is damage to all parameters

- Functioning of irrigation components
  The functionality of irrigation components is assessed based on their ability to deliver water appropriately and as needed. The functioning of irrigation asset components is divided into several main categories, namely structural, control, measurement, and supporting components [19]. Assessment of the functionality of each irrigation asset based on Kriteria Perencanaan bagian Bangunan KP-04.
  - Structure Functioning
    The functionality of each irrigation asset is adjusted to the type of asset. Types of irrigation assets consist of main buildings and complementary buildings. The structure functionality indicators are shown in Table. 4 s.d. Table. 11 [20].

    1) Main Building

Table 4. Structure Functioning Indicators

Score	Condition	Indicator
4	Good	No damage
3	Less Functioning	There is damage to 2 parameters
2	Bad	There is damage to 3 parameters
1	Not Functioning	There is damage to all parameters

Source : Kementerian Pekerjaan Umum KP-04, 2013

The parameters used are (1) no water level risers, (2) whirlpools/seepage, and (3) discharge not in accordance with the water level.

2) Bridge

Table 5. Bridge Functioning Indicators

Score	Condition	Indicator
4	Good	No damage
3	Less Functioning	There is damage to 2 parameters
2	Bad	There is damage to 3 parameters
1	Not Functioning	There is damage to all parameters

Source : Kementerian Pekerjaan Umum KP-04, 2013

The parameters used are (1) human/vehicle passability, (2) bridge arms and (3) footbridge plates.

3) Plunge

Table 6. Indicators of Plunge Functioning

Score	Condition	Indicator
4	Good	Elevation difference 1.10 - 1.50 m
3	Less Functioning	Elevation difference 0.80 - 1.10 m
2	Bad	Elevation difference 0.40 - 0.80 m
1	Not Functioning	Elevation difference 0.00 - 0.40 m

Source : Kementerian Pekerjaan Umum KP-04, 2013

4) Gutters, siphons, and cross culverts

Table 7. Indicators of Functioning of Gutters, Siphons, and Cross Culverts

Score	Condition	Indicator
4	Good	There is a filter grid
3	Less Functioning	Some of the filter grids are damaged
2	Bad	The filter grid is badly damaged
1	Not Functioning	There is no filter grid

Source : Kementerian Pekerjaan Umum KP-04, 2013

5) Drain Inlet

Table 8. Indicators of Drain Inlet Functioning

Score	Condition	Indicator
4	Good	Q input compliant
3	Less Functioning	Q input slightly less compliant
2	Bad	Q input is less suitable
1	Not Functioning	Q input is not suitable

Source : Kementerian Pekerjaan Umum KP-04, 2013

6) Mud Bags

Table 9. Indicators of Functioning of Mudbag

Score	Condition	Indicator
4	Good	Discarded Q is appropriate
3	Less Functioning	Discarded Q is slightly less appropriate
2	Bad	Discarded Q is less suitable
1	Not Functioning	Discarded Q is not suitable

Source : Kementerian Pekerjaan Umum KP-04, 2013

7) Canal Section

Table 10. Indicators of Canal Section Functioning

Score	Condition	Indicator
4	Good	There is <25% sedimentation
3	Less Functioning	There is 25% - 50% Sedimentation
2	Bad	There is 50% - 75% Sedimentation
1	Not Functioning	There is >75% sedimentation

Source : Kementerian Pekerjaan Umum KP-04, 2013

8) Animal Bathing Place

Table 11. Indicators of Functioning Animal bathing place

Score	Condition	Indicator
4	Good	Passable for livestock
3	Less Functioning	Slightly passable for livestock
2	Bad	Somewhat passable for livestock
1	Not Functioning	Not passable for livestock

Source : Kementerian Pekerjaan Umum KP-04, 2013

- Water Gate

Table 12. Indicators of Water Gate Functioning

Score	Condition	Indicator
4	Good	Door tightly closed
3	Less Functioning	Leakage <5%
2	Bad	Leakage 5% - 20%
1	Not Functioning	Leakage >20%

Source : Kementerian Pekerjaan Umum KP-04, 2013

- Measuring Building

Table 13. Indicators of Functioning of Measuring Building

Score	Condition	Indicator
4	Good	No damage
3	Less Functioning	There is damage to 2 parameters
2	Bad	There is damage to 3 parameters
1	Not Functioning	There is damage to all parameters

Source : Kementerian Pekerjaan Umum KP-04, 2013

The parameters used are (1) Peil scale, (2) does not meet the hydraulic requirements, and (3) construction is not suitable.

2.2 Operation and Maintenance of Irrigation Networks

The better the function of the infrastructure (canals and buildings), the higher the index. Conversely, the worse the infrastructure functions, the lower the index. The weight for canals/build- ings is 3 for primary canals, 2 for secondary canals, and 1 for tertiary canals. To determine the condition index of canals and buildings, see Table 14.

Table 14. Canal and Building Index

Index	Canal and Building Function	Recommendations / Actions
Index 4	Functioning 90% - 100%	Routine maintenance
Index 3	Functioning between 80% - 90%	Periodic maintenance is maintenance
Index 2	Functioning between 60% - 80%	Periodic maintenance is repair
Index 1	Functioning between <60%	Heavy repair or replacement

Source : Permen PUPR No. 12, 2015

3 Material and Methods

3.1 Research Location

This research was conducted in Sukatani Village, Cipeundeuy Surade Sub-district, Sukabumi Regency, West Java Province, with weir Coordinate Point 7◦22.23.17 S 106.◦34′21.39 E with service area in Sukatani Village and Cipeundeuy Village.

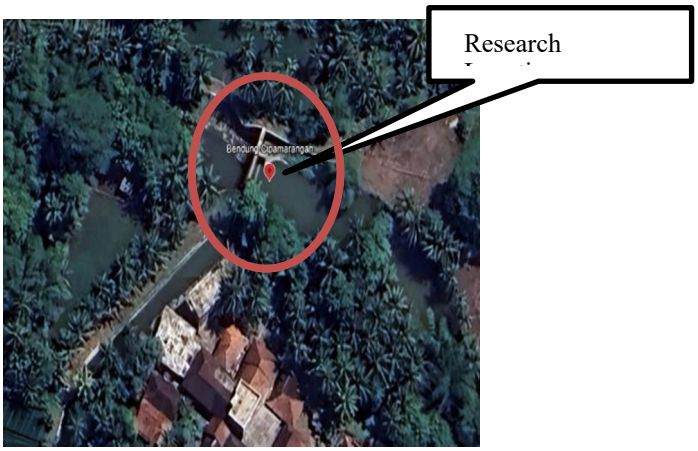

Fig. 1. Location of Cipamarangan Weir

Source : Google Earth, 2024

3.2 Research Methods

The method used in this research is quantitative descriptive method. Descriptive quantitative is a research method used to provide a description of a phenomenon using numerical data [21–23]. By identifying the condition and functioning based on indicators of structures, sluice gates and measur- ing buildings. Assessment of the condition and functioning of each irrigation component according to Peraturan Menteri Pekerjaan Umum and Perumahan Rakyat (PUPR) of 2015 and Kriteria Perencanaan Bagian Bangunan of 2013.

3.3 Data Collection

This research used a method to evaluate the performance of the Cipamarangan Irrigation Area system in Sukatani Village, Cipeundeuy Surade Sub-district, Sukabumi Regency. Primary data was obtained directly through observation of the physical condition and primary channel of DI. Cipamarangan, documentation of condition and functioning and condition assessment. While secondary data includes schematics of buildings and irrigation networks in DI. Cipamarangan, regional maps and service area data DI. Cipamarangan obtained from Dinas Pekerjaan Umum (PU) Sukabumi Regency. All these data are used to assess the condition and functioning of the Irrigation DI. Cipamarangan.

3.4 Research Flow Chart

Based on the research methods that have been carried out, the following flow chart can be established:

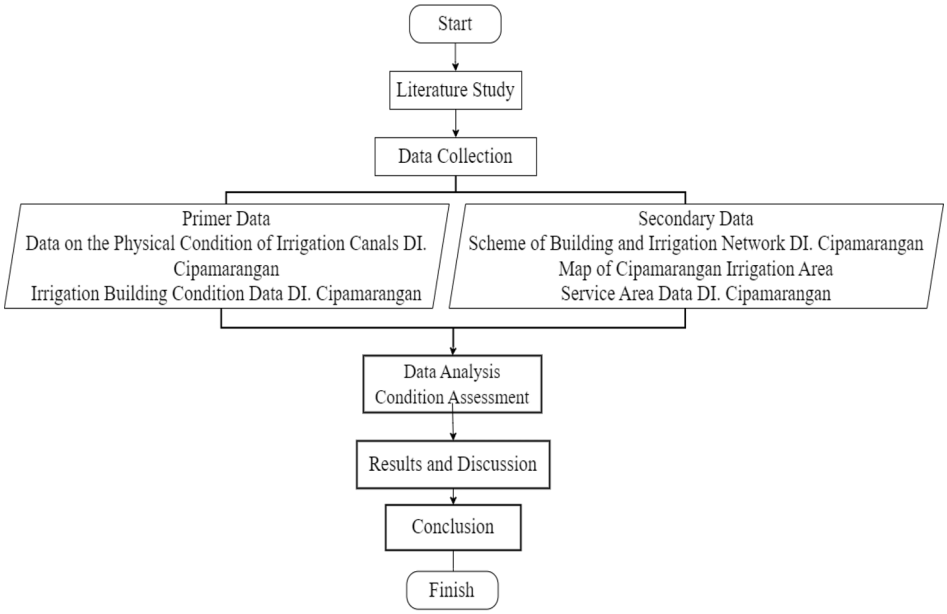

Fig. 2. Research Flow Chart

4 Results and Discussion

4.1 Physical Condition and Functioning of the Cipamarangan Irrigation Network

The physical condition of the irrigation network is an important aspect that affects the efficiency and effectiveness of the irrigation system in distributing water from the source to agricultural land. Good infrastructure not only supports optimal water delivery, but also affects agricultural productivity and the sustainability of the irrigation system as a whole. Evaluation of physical conditions in irrigation systems includes the examination of various elements of primary, secondary and tertiary canals [24]. This research was conducted only on the primary canal DI. Cipamarangan, the primary canal serves as the main canal that drains water from the main source, such as dams or rivers to secondary canals.

The functioning of irrigation networks plays a crucial role in ensuring optimal water availa- bility and distribution for agriculture. The main function of the irrigation system is to supply water effectively, minimize the lack or excess of water, and support the success of agricultural production. Based on the results of field observations, the physical condition of the primary canal in the Cipamarangan irrigation area experienced some significant damage, shown in Table 15.

Table 15. Physical Condition and Functioning of the Cipamarangan Irrigation Network

Condition	Total	Functionality	Total
Good	2	Good	5
Lightly Damaged	5	Less Functioning	3
Medium Damaged	6	Bad	0
Heavy Damage	12	Not Functioning	17
Missing	7	Missing	7

Source: Field Observation Results, 2024

4.2 Scheme of Irrigation Building Plan DI. Cipamarangan Based on Field Conditions

Irrigation building plan schemes should be developed considering the actual field conditions to ensure that the irrigation system can function effectively and efficiently [25]. After a detailed assessment of field conditions, the plan scheme needs to be adjusted to address identified problems and meet actual needs. These adjustments include not only design changes but also the application of relevant techniques and solutions to ensure that the irrigation system can function optimally under real field conditions .

Fig. 3 Scheme of Irrigation Building Plan D.I Cipamarangan Condition

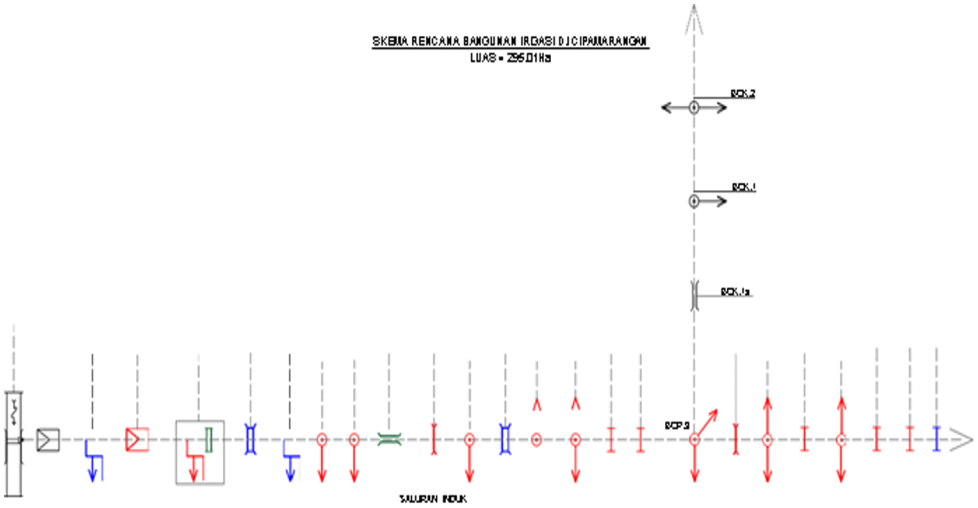

Fig. 4 Scheme of Irrigation Building Plan D.I Cipamarangan Functioning

4.3 Condition Assessment of Cipamarangan Irrigation Area

This assessment includes various components, each of which is given a certain weight value. This weight value is determined based on the role of each component in regulating water manage- ment. Components that have a smaller role in regulating the water system will get a lower weight, while components with a greater role will get a higher weight. In determining the condition index of canals and buildings using the following formula.

$$\text{Total Condition Index} = \text{Condition Value x Weight} \quad (1)$$

$$Index = \frac{\text{Total Condition Index}}{\text{Total Weight}} \quad (2)$$

Cipamarangan Irrigation Area condition assessment is shown in Table 16.

Table 16. Condition Assessment DI. Cipamarangan

No	Canal Type	Building Name	Registration Number	Building Condition Score	Weight	Total Condition Index	Building Function Score
1	Primary	Cipamarangan Weir	BCP.0	2.6	3	7.8	2.9
2	Primary	Drain	BCP. 1a	4	3	12	4
3	Primary	Measuring Building	BCP. 1b	3	3	9	1
4	Primary	Drain Culvert	BCP. 1c	2	3	6	3
5	Primary	Drain	BCP. 1c	1	3	3	1
6	Primary	Road Culvert	BCP. 1d	3	3	9	4
7	Primary	Drain	BCP. 1e	3	3	9	4
8	Primary	Tapping	BCP. 1	1	3	3	1
9	Primary	Tapping	BCP. 2	2	3	6	1
10	Primary	Gutter	BCP. 3a	2	3	6	3
11	Primary	People Bridge	BCP. 3b	1	3	3	1
12	Primary	Tapping	BCP. 3	1	3	3	1
13	Primary	Road Culvert	BCP. 4a	4	3	12	4
14	Primary	Tapping	BCP. 4	3	3	9	1
15	Primary	Tapping	BCP. 5	1	3	3	1
16	Primary	Waterfall Building	BCP. 6a	1	3	3	1
17	Primary	Waterfall Building	BCP. 6b	1	3	3	1
18	Primary	Tapping	BCP. 7	0	3	0	0
19	Primary	Waterfall Building	BCP. 8a	0	3	0	0
20	Primary	Tapping	BCP. 8	0	3	0	0
21	Primary	Tapping Share	BCP. 9	1	3	3	1
22	Primary	People Bridge	BCP. 10a	2	3	6	1
23	Primary	Tapping	BCP. 10	1	3	3	1
24	Primary	Waterfall Building	BCP. 11a	1	3	3	1
25	Primary	Tapping	BCP. 11	1	3	3	1
26	Primary	Waterfall Building	BCP. 12a	2	3	6	1
27	Primary	Waterfall Building	BCP. 12b	1	3	3	1
28	Primary	Waterfall Building	BCP. 12c	2	3	6	4
29	Primary	Tapping	BCP. 12	0	3	0	0
30	Primary	Drain	BCP. 13a	0	3	0	0
31	Primary	Gutter	BCP. 13b	0	3	0	0
32	Primary	Tapping	BCP. 13	0	3	0	0
Total					96	139.8	31%
Condition Index					Index	1.5	
Recommended Action					**Heavy Repair or replacement**		

Source: Analysis Result, 2024

5 Conclusion

Based on the analysis that has been carried out, the following conclusions and suggestions are obtained:

5.1 Conclusion

The condition of the Cipamarangan irrigation area in the study area is classified as not good with an index of 1.5 and its functioning is classified as not functioning with a percentage of 31%. The condition and functionality of the Cipamarangan Irrigation Area shows that the majority of buildings are in inadequate condition and function, overall this data indicates that the Cipamarangan Irrigation Area requires heavy repair or replacement to improve its condition and functionality. Buildings that require heavy repair and replacement include BCP. 1c, BCP.1, BCP. 3, BCP.5, BCP. 6a, BCP. 6B, BCP. 9, BCP. 10, BCP. 11a, BCP. 11 and BCP. 12b. repairs to these structures are essential to ensure the sustainability of Cipamarangan's irrigation function.

5.2 Suggestion

Based on the results of direct observation in the field and the results of the analysis, there needs to be an improvement in the operation and maintenance of Cipamarangan Irrigation. With the condition of the Cipamarangan irrigation network that is not good, it is expected to be repaired immediately so that there is not much water loss while in the canal so that the area that can be served increases. The application of monitoring technology and community participation in maintenance were identified as crucial steps to ensure the sustainability and optimization of irrigation systems. The findings are expected to provide practical guidance for managers and stakeholders in formulat- ing more effective repair and management strategies.

References

1. R. K. . Sampath, R. K. Young, Robert A. Sampath, Inadequate Management and Declining Infrastructure: The Critical Recurring Cost Problem Facing Irrigation in Asia*, *Inadequate Management and Declining Infrastructure: The Critical Recurring Cost Problem Facing Irrigation in Asia**, 1st ed. (Routledge, 2019)
2. N. Ungureanu, V. Vlăduț, and G. Voicu, Water Scarcity and Wastewater Reuse in Crop Irrigation, Sustainability **12**, 9055 (2020). https://doi.org/10.3390/su12219055
3. A. Malakar, D. D. Snow, and C. Ray, Irrigation Water Quality—A Contemporary Perspective, Water **11**, 1482 (2019). https://doi.org/10.3390/w11071482
4. H. S. El-Beltagi, A. Basit, H. I. Mohamed, I. Ali, S. Ullah, E. A. R. Kamel, T. A. Shalaby, K. M. A. Ramadan, A. A. Alkhateeb, and H. S. Ghazzawy, Mulching as a Sustainable Water and Soil Saving Practice in Agriculture: A Review, Agronomy **12**, 1881 (2022). https://doi.org/10.3390/agronomy12081881
5. A. J. Clemmens and A. R. Dedrick, Irrigation Techniques and Evaluations, in (Springer, Berlin, Heidelberg, 1994), pp. 64–103. https://doi.org/10.1007/978-3-642-78562-7_4
6. L. N. Allen and J. W. MacAdam, Irrigation and Water Management, in *Forages* (Wiley, 2020), pp. 497–513. https://doi.org/10.1002/9781119436669.ch27
7. P. Aryastana, C. A. Yujana, and I. M. Ardantha, Irrigation Water Management by Using Remote Sensing and GIS Technology to Maintain the Sustainability of Tourism

Potential in Bali, J. Infrastruct. Facil. Asset Manag. **2**, 63 (2020). https://doi.org/10.12962/jifam.v2i1.6965

8. A. N. Angelakıs, D. Zaccaria, J. Krasilnikoff, M. Salgot, M. Bazza, P. Roccaro, B. Jimenez, A. Kumar, W. Yinghua, A. Baba, J. A. Harrison, A. Garduno-Jimenez, and E. Fereres, Irrigation of World Agricultural Lands: Evolution through the Millennia, Water **12**, 1285 (2020). https://doi.org/10.3390/w12051285
9. J. F. Velasco-Muñoz, J. A. Aznar-Sánchez, A. Batlles-delaFuente, and M. D. Fidelibus, Sustainable Irrigation in Agriculture: An Analysis of Global Research, Water **11**, 1758 (2019). https://doi.org/10.3390/w11091758
10. D. H. dos S. Isaías, B. C. Cuamba, and A. J. Leão, A Review on Renewable Energy Systems for Irrigation in Arid and Semi-Arid Regions, J. Power Energy Eng. **07**, 21 (2019). https://doi.org/10.4236/jpee.2019.710002
11. Government Regulation Of The Republic Of Indonesia Number 20 Of 2006 Concerning Irrigation, *Government Regulation Of The Republic Of Indonesia Number 20 Of 2006 Concerning Irrigation* (2006)
12. Y. Zhuang, L. Zhang, S. Li, H. Liu, L. Zhai, F. Zhou, Y. Ye, S. Ruan, and W. Wen, Effects and potential of water-saving irrigation for rice production in China, Agric. Water Manag. **217**, 374 (2019). https://doi.org/10.1016/j.agwat.2019.03.010
13. Kementrian PUPR Republik Indonesia, Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 04/PRT/M/2015 concerning Criteria and Determination of River Areas, Kementeri. Pekerj. Umum Dan Perumah. Rakyat 1 (2015)
14. A. Suryanto Bere, D. Harisuseno, and T. Budi Prayogo, The Effect of Damage to Irrigation Assets on The Management of The Irrigation Network in The Weliman Irrigation Area, Malaka Regency-NTT, J. Tek. Pengair. **14**, 76 (2023). https://doi.org/10.21776/ub.pengairan.2023.014.01.7
15. R. A. Mel, D. P. Viero, L. Carniello, and L. D'Alpaos, Optimal floodgate operation for river flood management: The case study of Padova (Italy), J. Hydrol. Reg. Stud. **30**, 100702 (2020). https://doi.org/10.1016/j.ejrh.2020.100702
16. A. Momčilović Petronijević and P. Petronijević, Floods and Their Impact on Cultural Heritage—A Case Study of Southern and Eastern Serbia, Sustainability **14**, 14680 (2022). https://doi.org/10.3390/su142214680
17. V. Bjornlund and H. Bjornlund, Understanding agricultural water management in a historical context using a socioeconomic and biophysical framework, Agric. Water Manag. **213**, 454 (2019). https://doi.org/10.1016/j.agwat.2018.10.037
18. Regulation Of The Minister Of Public Works And Public Housing Of The Republic Of Indonesia Number 12/Prt/M/2015 Concerning Exploitation And Maintenance Of Irrigation Networks, *Regulation Of The Minister Of Public Works And Public Housing Of The Republic Of Indonesia Number 12/Prt/M/2015 Concerning Exploitation And Maintenance Of Irrigation Networks* (2015)
19. T. Prayogo, S. Wahyuni, and M. Iqbal, A Study of Irrigation Performance Index and Real Cost Value of Irrigation Operations and Maintenance in Surak Irrigation Area, Civ. Environ. Sci. **004**, 030 (2021). https://doi.org/10.21776/ub.civense.2021.00401.4
20. Building Section Planning Criteria, *Building Section Planning Criteria* (2013)
21. J. Bloomfield and M. Fisher, Quantitative research design, J. Australas. Rehabil. Nurses' Assoc. **22**, 27 (2019). https://doi.org/10.33235/jarna.22.2.27-30

22. H. Taherdoost, What are Different Research Approaches? Comprehensive Review of Qualitative, Quantitative, and Mixed Method Research, Their Applications, Types, and Limitations, J. Manag. Sci. Eng. Res. **5**, 53 (2022). https://doi.org/10.30564/jmser.v5i1.4538
23. H. K. Mohajan, Quantitative Research: A Successful Investigation in Natural and Social Sciences, J. Econ. Dev. Environ. People **9**, 50 (2020)
24. I. Sajid, B. Tischbein, C. Borgemeister, and M. Flörke, Performance Evaluation and Water Availability of Canal Irrigation Scheme in Punjab Pakistan, Water (Switzerland) **14**, 1 (2022). https://doi.org/10.3390/w14030405
25. K. Obaideen, B. A. A. Yousef, M. N. AlMallahi, Y. C. Tan, M. Mahmoud, H. Jaber, and M. Ramadan, An overview of smart irrigation systems using IoT, Energy Nexus **7**, 100124 (2022). https://doi.org/10.1016/j.nexus.2022.100124