



Potential Of Water Resources For The Development Of Organic Agricultural System In The Downstream Area Of Pakerisan Watershed

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ABSTRACT

Bali is known as one of the world's tourism destinations. This condition must always be preserved. One of the supports that must exist for sustainability is the availability of adequate food, both in quantity and quality. Good quality food is food that is not contaminated or often called organic food. Gianyar regency is one of the regencies in Bali, is one of the tourist destinations visited by many tourists. One of the watersheds in Gianyar regency is Pakerisan watershed. It is a very wide area for agricultural cultivation from upstream to downstream, which is considered as the source of the closest food supply to both the needs of residents and tourists. The dominant crops cultivated in paddy fields are rice and palawija crops. It is expected that food from this cultivation is organic food. The occurrence of pollution in crops can be caused by the use of chemical fertilizers, pesticides and also as a result of waste disposal to the river. The residue of chemical fertilizers, pesticides and wastes will flow from upstream to downstream, resulting the most potentially polluted water resources are in the downstream area. This study aims to study the potential of water resources for the development of organic farming systems in the downstream area of Pakerisan watershed. This research is a field research and laboratory research. Research indicates that the potential of irrigation water in the downstream area of Pakerisan watershed (Medahan irrigation area), in terms of water availability and heavy metal content, suitable for the development of organic agriculture, however, it is not appropriate in terms of carbonate content.

Keywords: Potential water resources, Pollution, Organic Farming, Pakerisan Watershed

I. INTRODUCTION

1.1 Background of Study

Pakerisan watershed is located in Gianyar Regency. This watershed is considered as a tourist attraction that covers a very wide area, of which this irrigation landscape of watershed has been established as a world cultural heritage since 29 June 2012 (Gede Agung, 2016). This predicate should be maintained, for example through the provision of pollution-free water, keeping the vegetation green, as well as synergizing the agricultural sector with tourism. The Pakerisan watershed has great potential for the provision of food both for the needs of the population and for tourists. The types of crops cultivated in the downstream watershed area, that is Medahan Irrigation Area, are dominantly rice and palawija crops. The yields obtained

from this farming are expected to be not polluted or remain as a source of organic food in a sustainable manner.

The cultivated plants will flourish and the yields are in high quality and quantity if the growing conditions are fulfilled. This growing conditions can be fertile soil, suitable climate, appropriate cultivation technology, adequate water discharge and appropriate irrigation water quality. At first, nature is naturally capable of providing such growing conditions. But as time passes, the population continues to grow, human needs in various sectors continue to grow, nature naturally no longer able to meet these growing requirements. This fact continues and develops until there are problems of global warming, climate change, environmental damage, water pollution so that appropriate strategies are needed to anticipate it. On the other hand, the fact that is not less important as a result of the rapid progress of development is the occurrence of land conversion.

The land conversion continues to grow, for example as a residence (housing), tourism/hotels, businesses/home industries, farms, public facilities and other designations. The transfer of this land function naturally also causes a change of activity on the land itself. Previously the land was only used for agricultural purposes, then turned into non-agricultural purposes with a very diverse activity. All of these activities produce waste either, solid, liquid, or other forms of waste, which are often discharged into rivers or irrigation canals. Similarly, the use of chemical fertilizers and pesticides in the agricultural sector can contribute to pollution in irrigation water in the upstream, middle and especially in the downstream area. All of these actions can lead to water pollution for irrigation.

The poor quality of irrigation water endangers plant growth and lowers production. To support food self-sufficiency, the continuity of the food production process requires appropriate irrigation water quality. Based on the scoring classification by applying the Storet method, the classification of the water belongs to class D, with the characteristics of water is heavily polluted, with a score of ≥ 31 , which results in adverse impacts for irrigation (Bambang Rahadi and Novita Lusiana, 2012). Water sources with large water discharge cannot be used for irrigation if the water quality is poor. Currently, farmers, especially those in the downstream area of Pakerisan watershed, do not know whether irrigation water is suitable or not for irrigation.

Based on the above explanation, it can be seen that research on "Potential Water Resources for the Development of Organic Agricultural System in the Downstream Area of Pakerisan Watershed" needs to be done.

1.2 Aims of Study

This study aims to identify:

- a. Availability of irrigation water of Medahan irrigation area (downstream area of Pakerisan watershed) for the development of organic farming.
- b. the quality of Irrigation water in Medahan irrigation area for the development of organic farming.

- c. The content of heavy metals in irrigation water in the Irrigation Area of Medahan for the development of organic farming

II. RESEARCH METHOD

2.1. Location and Time

The research was conducted in Medahan Irrigation Area, Pakerisan watershed, Gianyar Regency from April 2017 until October 2017. The landscape of Pakerisan watershed has been designated as World Cultural Heritage by UNESCO since 2012.

2.2. Instrument of Study

Materials and tools used in this research are water, irrigation facilities in the Irrigation Area of Medahan and in Subak area, chemicals for analysis, laboratory equipment, bucket, roll meter, rope, scissors, and stationeries.

2.3 Method of Study

2.3.1 Field Research

Field research involves collecting data and information (primary and secondary data) in terms of:

- a. Pakerisan watershed

In this activity, the data collected includes geographical location, geological, hydrological conditions, as well as climate obtained from the results of previous studies.

- b. *Subak* in the Medahan Irrigation Area

In this section collected data can be divided into the name and number of subak along with the extent of its area in the Medahan Irrigation Area

- c. Water Availability in the Medahan Irrigation Area

The data were collected from Pekaseh (the head of subak), farmers and observers of the Medahan dam water, and from previous studies.

- d. Planting Methods

The data collected were plant species, cropping pattern and production facilities. Data were recorded from *Pekaseh* (the head of *Subak*) and farmers through interviews by preparing a list of questions.

- e. Source and Type of Pollution,

Potential sources of pollutants and the type of pollutants was observed

- f. Waste Disposal Mechanism

The mechanism is meant to process from waste collection to disposal to river or irrigation channels

- g. Waste Management Technology.

The availability of tools, materials, and technologies used to process waste before disposal into irrigation canals was observed.

2.3.2 Laboratory Research

Laboratory research involves water sampling activities in the downstream area of Pakerisan Watershed (Medahan Irrigation Area). Water sampling was done in the channel and in the *subak* paddy field. The sampling of channel water carried out on the primary, secondary and tertiary channels, and each was taken 2 water samples. For sampling in *subak* rice field, 8 water samples were taken. The total water sample is 14. The water samples that have been obtained are taken directly to Analytical Laboratory of Udayana University for analysis.

The water quality parameters specified in the laboratory are: conductivity or electrical conductivity (EC), dissolved solids (TDS), acidity (pH), calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{++}), carbonate ($\text{CO}_3^{=}$), bicarbonate (HCO_3^-), sulphate ($\text{SO}_4^{=}$), chloride (Cl^-), potassium (K^+), nitrate (NO_3^-) and boron (B). For the heavy metals, consists of arsenic (As), lead (Pb), cadmium (Cd) and chromium (Cr) and they were analyzed by applying ICPE method.

2.3.3 Water Irrigation Quality Feasibility Test

In order to determine the feasibility of water for irrigation, the results of parameter values that have been analyzed in the laboratory are matched by using comparative descriptive method with existing water quality standards, based on Project Management Unit standard (1996, in Santosa, 2006), Bali Governor Regulation no. 8 of 2007 and Yusuf (2014).

If the feasibility of irrigation water quality is appropriate, then this suitability should be maintained sustainably. Conversely, if there is pollution or irrigation water quality is not appropriate, it should be checked whether there is or there is no waste management system and waste management technology in pollutant sources. Furthermore, it is necessary to find a better solution so that no pollution occurs. This solution will be closely related to field research data.

III. RESULT AND DISCUSSION

3.1 Field Research

3.1.1 Pakerisan Watershed

This source of information or data is obtained from previous studies conducted by Hatungkara Group in 2012 and also from the direct information obtained in the field.

- a. Pakerisan River and Petanu River are close to each other and both are located in Gianyar Regency. The stream crosses villages with a high cultural heritage background. Pakerisan river is covered in the territory of Sub SWS 03.01.18 while Petanu river is in the Sub SWS region 03.01.019. The Petanu and Pakerisan watersheds are located at $115^{\circ}15'54''$ - $115^{\circ}21'54''$ EL and $8^{\circ}16'40''$ - $8^{\circ}35'58''$ SL.

b. Condition of Geology and Hydrology

Petanu and Pakerisan watersheds are formed from tuff deposits and lava sediments of Buyan-Beratan lakes and Mount Batur. From the hydrogeological aspect of this watershed, in a small part of the upstream region, its geological conditions are formed from soils with very little water content of approximately 0.1 l / s. Most of the upstream soil conditions have a groundwater content of less than 1 l / s. In the middle zone has a soil condition with moderate water content of approximately 5 l / s. Meanwhile, in the most downstream zone has a water content of 10 l / s.

c. Climate

The closest rain station to the Medahan irrigation area is the Gianyar rain station. The annual rainfall has an average of 1,662 mm / yr with an effective rainfall of 1,415.20 mm / year, with annual evapotranspiration of 1210.80 mm / yr. This means that the amount of effective rainfall is greater than the evapotranspiration or water supply that exists in the Medahan irrigation area is greater than the water lost through evaporation. This shows that year-round water supply in Medahan irrigation area is sufficient. Climatologically, the data study showed a maximum average temperature of 27.20 °C, occurring in December, and a minimum average temperature of 22.50 ° C, occurring in August.

3.1.2 Subak in Medahan Irrigation Area

In the Pakerisan watershed, there are 15 Irrigation Areas. Of these 15 irrigation areas, the Medahan irrigation area is the most downstream irrigation area directly facing the coast. Medahan irrigation area is located exactly downstream of Gianyar city, adjacent to Gianyar city. The amount of subak that exist in Medahan irrigation area are 7 *subak*, they are Subak Peling (32.13 ha), Subak Jurit (30.3 ha), Subak Masceti (52.71 ha), Subak Celuk (45.04 ha), Subak Nengan (40.74 ha), Subak Abu (48.88 ha) and Subak Padang Legi (25.29 ha). Overall, the area of Medahan irrigation area is 275.09 ha.

3.1.3 Water Availability

According to the survey results from pekaseh and farmers, it is known that water availability in Medahan irrigation area is available and sufficient throughout the year. However, the water discharge in the rainy season is greater than that in the dry season. As already stated before, based on data it can be seen that the annual rainfall climate is higher than the annual evapotranspiration. Based on a study conducted by Hastungkara Group (2012), it was proposed that the irrigation water needs in Medahan irrigation area within a year ranged from 0 - 0.699 m³ / sc, the availability of water in a year ranged from 0.002 - 3.362 m³ / sc. This means that the water supply is greater than the needs. Furthermore, it was also stated that the water balance in Medahan irrigation area is positive; there has never been water shortage during the year. In terms of quantity, it shows that in the irrigation area of Medahan, the water availability is sufficient for the development of organic farming. This is supported by water discharge data from the dam of Medahan, during

the past year period from November 2016 to October 2017 (Table 1). The minimum water discharge availability in March 2017 was 855 l/s or 0.855 m³/s. With a maximum requirement of 0.699 m³/s, then this minimum discharge of its availability has exceeded the maximum requirement.

Table 1. Water Discharge of the Dam in Medahan (l/s)

No.	Month and Year	Debit (l/s)		
		Maximum	Minimum	Average
1	November 2016	966	905	935
2	December 2016	987	925	956
3	January 2017	1029	946	988
4	February 2017	1008	915	962
5	March 2017	966	855	911
6	April 2017	946	905	926
7	May 2017	956	895	926
8	June 2017	966	895	931
9	July 2017	956	905	931
10	August 2017	966	925	946
11	September 2017	987	905	946
12	October 2017	977	936	956
	Total	11.710	10.912	11.314
	Average	976	909	943

Source: observers of the Medahan dam water (2017)

3.1.4 Planting Method

The types of plants cultivated in the Medahan irrigation area are rice and palawija crops. The rice varieties cultivated are Ciherang and Cigelis, for Palawija plants such as corn, soybean and peanut. Corn covers 80%, peanuts 12% and soybeans 8%. Planting pattern that is done is rice - rice – palawija crops. The average rice yield is 7 tons / ha. The types of fertilizer used are manure (the result of simantri), urea fertilizer, and NPK ponska fertilizer.

In order to control pest and disease, farmers are still mostly (80%) using inorganic pesticides, for example Komidor and Trident. There is only a small percentage of farmers (20%) use cow urine as a result of simantri, a government program for pest and disease control. The dosage of fertilizer used is organic fertilizer is 5 kg /are (cow dung as the result from simantri program), urea is 3 kg / are, and NPK ponska is 3 kg / are. Simantri program in the future should be improved and developed, because the purpose of agriculture in the future is organic farming. The improvement and development of Simantri program is expected to reduce the use of inorganic fertilizers and pesticides.

3.1.5 Sources and Types of Potentially Polluting Materials

Potential sources or activities as a polluter are waste disposal from households, stalls, restaurants, hotels / inns, markets, car wash shops and others. Some activities such as washing and bathing in irrigation canals also have the potential to become pollutants. Potential types of pollutants are solid / liquid waste disposal, agricultural activities such as the use of fertilizers and inorganic pesticides, soaps or detergents and garbage.

3.1.6 Waste Disposal Mechanism

Waste sourced from a potentially pollutant site as mentioned above is directly discharged into a river or irrigation channel without prior management. Trash is usually collected separately and thrown to landfills by garbage collectors. However, people often do not throw garbage in its place. This of course complicates the garbage man and causes pollution. Littering has become a habit. To overcome this problem, coordination between village officials, related institutions and village communities should be done in finding the best solution for the common good. Any waste that will be discharged into river or irrigation channel should be managed first, after meeting the quality standard, then can be discharged to the water body.

3.1.7 Waste Management Technology

In the Medahan irrigation area there is no waste management technology yet. Waste is disposed conventionally to river or irrigation channels. For sustainable irrigation, this waste management technology is indispensable to support sustainable agriculture. In addition, there is a need for awareness and understanding of the community about pollution arising from the actions of the community itself.

3.2 Laboratory Research

3.2.1 Quality of Irrigation Water in Channels

Determination of irrigation water quality in channel includes primary, secondary and tertiary channel.

Data on the determination of irrigation water quality are presented in Table 2.

Table 2. Quality of irrigation water in primary, secondary and tertiary channels

No.	Parameter	Unit	Primary Channel	Secondary Channel	Tertiary Channel	Feasibility for Irrigation
1.	Electrical conductivity	$\mu\text{S/cm}$	468,75	593,75	515,63	Feasible
2.	Dissolved solids	mg/l	300	380	330	Feasible
3.	Acidity (pH)	-	7,97	8,05	7,98	Feasible
4.	Calcium (Ca^{++})	mg/l	3,38	3,31	2,91	Feasible
5.	Magnesium (Mg^{++})	mg/l	17,8	17,2	14,5	Feasible
6.	Sodium (Na^{++})	mg/l	34,0	32,3	32,4	Feasible
7.	Bicarbonate (HCO_3^-)	mg/l	231,8	187,58	230,0	Feasible
8.	Carbonate ($\text{CO}_3^{=}$)	mg/l	24	28,50	11,70	Unfeasible
9.	Sulfate ($\text{SO}_4^{=}$)	mg/l	52,901	65,56	110,11	Feasible
10.	Chloride (Cl^-)	mg/l	27,761	27,76	28,97	Feasible
11.	Potassium (K^+)	mg/l	5,00	4,35	3,50	Feasible
12.	Nitrate-Nitrogen (NO_3^-)	mg/l	5,341	5,806	5,76	Feasible
13.	Boron (B)	mg/l	0,58	0,039	0,35	Feasible
14.	BOD	mg/l	9,37	14,03	15,42	Feasible
15.	COD	mg/l	21,34	30,24	34,06	Feasible

Source : Analytic Laboratory of Udayana University (2017)

The data in Table 2 show that all parameters observed include the category suitable for irrigation, except the carbonate parameter ($\text{CO}_3^{=}$). Judging from the feasibility standards for carbonate parameters, the feasibility threshold is 3 mg / l (Project Management Unit, 1996 in Santosa, 2006). The results of this carbonate content analysis ranged from 11.70 mg / l to 28.50 mg / l, where the lowest was found in the tertiary canal, while the highest was found in the secondary canal. This is suspected to be caused by detergents, soaps, shampoo, and the like used by residents when washing and bathing in irrigation canals. It can be proved, because during the observation of Medahan irrigation networks, it was found that the local residents bathing and washing in secondary channels. It may also be caused by household waste disposal, food stalls, restaurants, hotels / inns, car wash workshops, which are located adjacent to each other

3.2.2 Quality of Irrigation Water in Paddy Field

The Medahan Irrigation Area consists of seven subak as already mentioned in the field research. To determine the quality of irrigation water in paddy fields, water is taken from three subak namely Subak Peling (representing upstream), Subak Abu (representing center/middle) and Subak Padang Legi (representing downstream). The quality of irrigation water in these three subak can be presented in Table 3.

The data in Table 3 show all parameters observed include the category of suitability for irrigation, except the carbonate parameter ($\text{CO}_3 =$). Judging from the feasibility standards for the carbonate parameter, the feasibility threshold is 3 mg / l (Project Management Unit, 1996 in Santosa, 2006). This carbonate content analysis showed results that ranging from 27 mg / l to 36 mg / l in the most upstream area (Subak Peling), then increased in the middle area (Subak Abu), and the highest found in the most downstream area (Subak Padang Legi). It is possible that this could happen because of the detergent, soap, or shampoo used by villagers when washing and bathing in the irrigation canals. The proof is that at the time of the observation in the Medahan irrigation system, the local people are washing and bathing in the channels, one of them is the secondary channel. Carbonate is carried away by irrigation water and then settles in subak of the paddy field itself. The subak located downstream (Subak Padang Legi) becomes the last accumulation of the carbonate so that the highest carbonate content can be found in the Padang Legi subak.

Based on the research conducted in the irrigation area of Mambal (Badung regency), there is a tendency in term of the decreasing quality of irrigation water. It was found that the more downstream, the quality of irrigation water decreased.

Table 3. The Quality of Irrigation Water in Paddy Field

No.	Parameter	Unit	Subak Peling (Upstream)	Subak Abu (Middle)	Subak Padang Legi (Downstream)	Feasibility for Irrigation
1.	Electrical conductivity	$\mu\text{S/cm}$	531,25	562,5	578,13	feasible
2.	Dissolved solids	mg/l	340	360	370	feasible
3.	Acidity (pH)	-	8,85	8,74	7,96	feasible
4.	Calcium (Ca^{++})	mg/l	2,60	2,91	3,15	feasible
5.	Magnesium (Mg^{++})	mg/l	13,4	15,1	17,0	feasible
6.	Sodium (Na^{++})	mg/l	31,7	30,8	35,7	feasible
7.	Bicarbonate (HCO_3^-)	mg/l	198,25	196,73	183,0	feasible
8.	Carbonate ($\text{CO}_3^{=}$)	mg/l	27	30	36,0	unfeasible
9.	Sulfate ($\text{SO}_4^{=}$)	mg/l	59,78	58,100	77,25	feasible
10.	Chloride (Cl^-)	mg/l	30,175	27,761	29,21	feasible
11.	Potassium (K^+)	mg/l	2,79	3,36	3,92	feasible
12.	Nitrate-Nitrogen (NO_3^-)	mg/l	3,39	4,29	1,66	feasible
13.	Boron (B)	mg/l	0,30	0,32	0,364	feasible
14.	BOD	mg/l	7,84	16,42	13,510	feasible
15.	COD	mg/l	15,21	35,36	25,24	feasible

Source : Analytic Laboratory of Udayana University (2017)

It was found that there were 320 mg /l of solids dissolved in the primary channel, 380 mg / l in secondary channels, and 410 mg / l in tertiary channels (Santosa and Dharma, 2016). This is likely also caused by waste disposal from household, food stalls, and restaurants; because, the location of paddy fields, residential areas, stalls, and restaurant are adjacent to each other. The rice field in the most downstream area (Subak Padang Legi) is considered as the accumulation of carbonate (HCO_3^-); therefore, the carbonate content becomes the highest.

3.2.3 Heavy Metal Content in Irrigation Water

The content of heavy metals in irrigation water is divided into two; they are the heavy metal content in the channel and in the paddy field.

a. Heavy Metal Content in Irrigation Water in Channels

The heavy metal content of irrigation water in the canals is presented in Table 4. The data in Table 4 shows that the heavy metal content of Arsenic (As) of irrigation water in the channel from upstream to downstream, from primary to tertiary canals ranges from 0.0043 to 0, 0051 mg / l. The feasibility limit of arsenic (As) content for irrigation is maximum 1 mg / l (Bali Provincial Government, 2007).

Table 4. The Heavy Metal Content of Irrigation Water in the Channel

No.	Parameter	Unit	Primary Channel	Secondary Channel	Tertiary Channel	Feasibility for Irrigation
1.	Arsenic (As)	mg/l	0.0051	0.0050	0.0043	feasible
2.	Cadmium (Cd)	mg/l	Ttd	ttd	ttd	feasible
3.	Chromium (Cr)	mg/l	Ttd	ttd	ttd	feasible
4.	Timbale (Pb)	mg/l	Ttd	ttd	ttd	feasible

Source : Analytic Laboratory of Udayana University (2017)

This table above shows that the heavy metal content of Arsenic (As) is still below the threshold. It means that it is very safe for irrigation. The amount of other heavy metals such as cadmium (Cd), chromium (Cr) and lead (Pb) contained in irrigation water are considered little that they cannot be detected; therefore, it is also very safe for irrigation.

b. Heavy Metal Content in Irrigation Water in the Paddy Field

In addition to irrigation water quality determination, the determination of heavy metal content in irrigation water in paddy fields is also done in Subak Peling (representing upstream), Subak Masceti (representing Central) and Subak Padang Legi (representing downstream). The observed data in terms of the heavy metal content of irrigation water are presented in Table 5.

Table 5. Heavy Metal Content in Irrigation Water in Paddy Field

No.	Parameter	Unit	Subak Peling (Upstream)	Subak Abu (Middle)	Subak Padang Legi (Downstream)	Feasibility for Irrigation
1.	Arsenic (As)	mg/l	0.0039	0.0045	0.0049	feasible
2.	Cadmium (Cd)	mg/l	nd	nd	nd	feasible
3.	Chromium (Cr)	mg/l	nd	nd	nd	feasible
4.	Timbale (Pb)	mg/l	nd	nd	nd	feasible

Source : Analytic Laboratory of Udayana University (2017); nd = not detected

The data in Table 5 indicate that the heavy metal content of Arsenic (As) in irrigation water in paddy fields from upstream to downstream ranges from 0.0039 to 0.0049 mg / l. The limit of the feasibility of arsenic (As) content for irrigation is maximum 1 mg / l. This means that the heavy metal content of Arsenic (As) is still below the threshold, which means it is very safe for irrigation. The amount of other heavy metals such as cadmium (Cd), chromium (Cr) and lead (Pb) contained in irrigation water in paddy field are also considered little that they cannot be detected; therefore, it is also very safe for irrigation.

The data on the heavy metal content of irrigation water in Table 4 and Table 5 shows that the heavy metal content of irrigation water from upstream to downstream (from the primary channel to the rice field) is still very feasible and very safe for irrigation.

IV. CONCLUSION AND SUGGESTION

4.1 Conclusion

According to the results and discussions described above, the results of the study can be summarized as follows:

- a. Water availability in the Medahan irrigation area (downstream area of Pakerisan watershed) is sufficient throughout the year for the development of the organic farming system.
- b. The quality of irrigation water in Medahan irrigation area is not suitable for the development of organic agriculture, because, the carbonate content ($\text{CO}_3 =$) of the irrigation water, both in the channel and subak exceeds the feasibility threshold.
- c. The content of heavy metal in irrigation water in Medahan irrigation area is suitable for the development of the organic agriculture.

4.2 Suggestion

There are several suggestions that can be given:

- a. In potentially polluted sources or places such as households, stalls, restaurants, lodging, markets, workshops it is necessary to have waste management tools/materials to ensure water quality, making it suitable for sustainable irrigation.
- b. It is necessary to provide a place for washing and proper public bathrooms, therefore, the villagers do not wash or bathe in irrigation channels, because soap and detergent used is potential to cause pollution in irrigation water
- c. There should be coordination between the villagers, village officials and related institutions to handle waste issues in order to maintain the quality of irrigation water, as well as to maintain environmental cleanliness.
- d. Simantri program needs to be developed and improved

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