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Evaluation of the Sustainability of Groundwater Irrigation Development in Tejakula and Kubu Districts

Ketut Budi Susrusa

Agribusiness Department, Faculty of Agriculture, Udayana University, Denpasar, Indonesia

Widhianthini

Agribusiness Department Faculty of Agriculture Udayana University, Denpasar, Indonesia
Corresponding author email: widhiantini@unud.ac.id

Putu Udayani Wijayanti

Agribusiness Department Faculty of Agriculture Udayana University, Denpasar, Indonesia

Ketut Ayu Yuliadhi

Agroecotechnology Department Faculty of Agriculture Udayana University, Denpasar, Indonesia

Abstract---The Sustainable Agricultural Irrigation Development Project in Buleleng and Karangasem (SDIABKA) is a project activities aim to increase community access to irrigation infrastructure and facilities needed to support increased agricultural productivity and food subregional security in north-east Bali. Institutional development of tubwell users group (TUG) has been carried out which in turn will be able to support the management of efficient and sustainable groundwater irrigation facilities both economically and environmentally. It is very important to know the sustainability of the project such as the financial independence of the irrigation system, irrigation water supply, and the sustainability status. This valuable experience of developing groundwater irrigation is useful for lessons learned. The target population in this study is 24 SDIABKA TUGs. The TUGs located is in 9 villages in Tejakula and 3 villages in Kubu District. Sampling was carried out by stratified random sampling method based on agro-climate and socio-economic aspect, namely: (1) Eight TUGs located in Tianyar District represents the agro-climate area of the solum covered by the sand of Gunung Agung eruption and less developed social economy; (2) Eight TUGs located in around the capital city Tejakula District represents better solum (agro-climate areas) and advanced social economy (Tejakula, Bondalem, Penuktukan); (3) Eight TUGs located in the rest of village in Tejakula District represent better solum (agro-climate areas) and moderate in socio-economic. In each stratum two TUGs are chosen by a simple random method, thus the total number of samples is 6 TUGs. This study revealed that sustainability in 3 of the 6 samples seemed worrying, which was reflected by the reduced number of group members, the low achievement of the revolving fund accumulation target, and the dependence on the government for the operation and maintenance cost of the irrigation system. The use of irrigation water is very low which is reflected in the low operating capacity of the pump installed. From the point of view of the sustainability status of groundwater irrigation development, the physical-ecological, socio-cultural, and institutional dimensions have a very sustainable status. The economic and infrastructure-technology dimensions are classified as quite sustainable. There are several sensitive variables (that need to be improved) including: the availability of groundwater for the last 5 years, availability of funds for pump well maintenance, pump well management costs, active cooperation in TUGs in groundwater irrigation management, use of pump well technology, technological suitability with the expected quality standards of agricultural products, and the availability of capital institutions for TUGs. To improve the project outcome, especially in the cultivation of annual crops and strengthen the sustainability of the development of groundwater irrigation, intensive agriculture extension and assistance in the management of sustainable groundwater irrigation should be carried out. Meanwhile, operations and maintenance related to relatively complex technical aspects still require government assistance.

Keywords---agricultural, evaluation, farmers, project, sustainable.

Introduction

The "Sustainable Development of Irrigated Agriculture in Buleleng and Karangasem" (SDIABKA) project is a continuation of the "North Bali Ground Water Irrigation and Water Supply Project" (NBGIWSP) which was closed in September 1999. When NBGIWSP was closed, 30 bore wells were built but only 15 wells were built which operate as a groundwater irrigation system, while the remaining 15 wells have not yet operated because they have not been equipped with irrigation channels. Furthermore, the installation of irrigation channels in 15 boreholes that have not yet operated was carried out in the SDIABKA project. In addition, the SDIABKA project also built 10 additional groundwater irrigation systems in nine new locations. All of these activities aim to increase community access to irrigation infrastructure and facilities which in turn will support increased agricultural productivity and subregional food security (Karhu et al., 2011; Rockström et al., 2010).

The overall planning of these activities has been outlined in the Overall Work Plan and detailed every year in the Annual Work Plan. The construction of a groundwater irrigation system involves three occupational groups namely construction activities, agricultural development, and empowerment of beneficiary communities. Various activities related to agricultural development and empowerment of farmers have been carried out by the SDIABKA Agricultural Development Division (ADD), including: Identifying and introducing suitable and profitable farming systems following location (agricultural diversification), institutional development, and the development of farm women. All of these activities are very important to increase farmers' income which in turn will be able to support the management of efficient and sustainable groundwater irrigation facilities both economically and environmentally.

With the start of the operation of the irrigation system in TUGS SDIABKA, since early 2005 agricultural development activities have been concentrated on 24 TUGS SDIABKA. At the same time, agricultural development activities in 15 TUGs NBGIWSP were reduced and only limited to group empowerment.

To measure the achievement of the results of implementing programs that have been determined during the project period, this monitoring survey was carried out (Perminova et al., 2008; Turner & Müller, 2003). The results of the monitoring survey are in the form of a description of the TUGs condition in terms of group finances, organization, ability to maintain pumps, electric panels, and irrigation networks, as well as water availability for group members. Furthermore, the latest TUGs conditions were compared with the "initial stakes" that were reported in 2004 in the BASELINE SURVEY REPORT 24 SDIABKA WELLS FARMER GROUPS (TUGs).

Based on the description above, the main objective of this study is to monitor the sustainability of irrigation development for dry-land agriculture. The results of this monitoring will be useful to know the extent of progress that has been achieved by beneficiary farmers in managing the groundwater irrigation system (Beedell & Rehman, 2000; Bekele & Drake, 2003). In addition, the results of this monitoring will be useful as feedback in developing and determining subsequent programs to improve the independence of TUG management.

Research Methods

The target population in this study is 24 SDIABKA TUGs located in 9 villages in Tejakula District and 3 villages in Kecamatan Kubu. Sampling is done by stratified random sampling. Sampling was carried out by stratified random sampling method based on agro-climate and socio-economic, namely: (1) Tianyar Region represents the agro-climate area of the solum land covered by the Great Mount eruption sand and 8 TUGs less developed social economy; (2) Tejakula sub-district around the capital city of the sub-district represents agaroklimat solum, good land and advanced social economy (Tejakula, Bondalem, Penuktukan) of 8 TUGs; (3) The other Tejakula subdistricts represent 8 TUGs agro-climate areas and good socio-economic land. In each stratum two groups are chosen by a simple random method, thus the total number of samples is 6 TUGs.

To analyze the sustainability of groundwater irrigation system development, the Rapfish technique (Rapid Appraisal for Fisheries) is used (Fisheries Centre, 2002). This ordination technique determines something in a measurable order with the Multi-Dimensional Scaling (MDS) method of the groundwater irrigation system. MDS is a "multivariate" method that can handle metric data (ordinal and nominal scales) and statistical techniques that try to transform multi-dimensional into lower dimensions (Fauzi, 2005). These dimensions are physical-ecological, economic, socio-cultural, infrastructure-technology and institutional, each of which is represented by attributes or variables of sustainability. Attributes of each dimension as well as good and bad criteria with scores according to the opinions of experts and stakeholders related to the system under study. Each attribute in each dimension is given a score that reflects the condition of sustainability. The range of scores is determined based on criteria that can be found from the results of field observations and secondary data. The score ranges from 0-3, depending on the state of each attribute, which is interpreted from bad to good. A bad score reflects the most unfavorable condition for the

sustainability of the subak system, whereas a good score reflects the most favorable condition for the sustainability of the subak system. The sustainability index values in this analysis are grouped into 4 categories of sustainability status based on the value of the Rap-GWI (Rapid Appraisal for Ground Water Irrigation) analysis index value listed in Table 1.

Table 1
Sustainability index category of pump well system

Index value	Category	Sustainable status
0-25,00	Bad	Not sustainable
25,01-50,00	Not enough	Less sustainable
50,01-75,00	Enoug	Quite sustainable
75,01-100,00	Well	Very sustainable

Source: Fisheries, 2002

Comparative analysis of sustainability between dimensions is carried out, where the sustainability index value of each dimension is visualized in the form of a kite diagram of the physical-ecological aspects, economic aspects, socio-cultural aspects, infrastructure-technology aspects, and institutional aspects which are depicted in the following figure.

Results and Discussion

TUGs Progress

Progress of TUGs is measured by the increase in the number of members, and the area of irrigation. Three of the six TUGs samples showed the addition of group members and the area of irrigation namely JLH-09, BDM-32, and PKT-08. The highest increase occurred in JLH-06. The three TUGs are located in an area that is agro-climate and socioeconomic better condition than the other three TUGs samples. Three of the six TUGs samples instead showed an increase in the number of members and the area of irrigation as a result of a decrease, namely: TMB-59, TTG-06, and TTM-28. The highest decrease occurred in TTG-06 (Table 2). To sustainability, increasing the number of members to a certain extent is recommended to maximize the installed capacity of the pump to increase the efficiency of pump operation.

Table 2
Progress of the number of members and irrigation land in the 2019 SDIABKA TUGs sample

TUG	Group Member (person)			Command area (ha)		
	2005	Addition	2019	2005	Addition	2019
JLH- 09	76	31	107	19	7.75	26.75
BDM-32	57	6	61	19.23	3.5	22.73
PKT-08	62	7	69	15	12	27
TMB-59	46	0	43	20.63	0	
TTG-06	64	0	33	0	0	
TTM-28	42	0	41	0	0	

TUGs revolving funds

One of the TUGs empowerment activities undertaken by the project is to encourage the formation of revolving funds at each TUG. The source of money for the formation of this revolving fund is to convert subsidized electricity costs from the government for 3 years into the accumulation of revolving funds. The technique of converting government subsidies into revolving funds is carried out in the following way. In each TUG a policy is stipulated that during the subsidy period members are not completely free of using water but are required to pay a portion of the subsidized water fee. The payment for part of the water costs will then be collected in groups which at the end of the subsidy are targeted to accumulate a revolving fund of IDR100 million.

Table 3 shows that the achievement of the revolving fund target in 3 of 6 TUGs samples is only under 50%, namely TMB-59, TTG-06, TTM-28. Meanwhile, the other 3 TUGs samples varied between 60-100 percent. The low

target achievement in the three KPSPs above shows low awareness of the need for revolving funds to reserve operations and maintain the irrigation system. Even in TTG-06 where the lowest targeted, rolling achievements that have been collected are shared by group members for personal use so that the numbers become very small.

Table 3
TUGs revolving funds 2006-2019

TUG	Revolving Funds (IDR)		Revolving Funds Accumulation Target (Rp)	Target Achieved (%)
	2006	2019		
JLH-09	24.740.503	81,600,000	100.000000	81,60
BDM-32	30.975.800	100,000,000	100.000000	100,00
PKT-08	25.000.000	60,000,000	100.000000	60,00
TMB-59	21.832.950	25,000,000	100.000000	25,00
TTG-06	15.000.000	11,500,000	100.000000	11,50
TTM-28	6.946.500	45,728,000	100.000000	45,73

Maintenance of pumps, panels and irrigation schemes

Irrigation system sustainability in terms of the ability of the group to pay for maintenance shows things that are not different from the indicators that have been explained before. Three of the six TUGs namely JLH-09, BDM-32, and PKT, 08 were able to finance damage through group cash, while the other three groups namely TMB-59, TTG-06, and TTM-28 were unable to finance the damage at their ability but still need government help Table 4).

Table 4
Type of damage, repair costs, Source of cost, the source of costs, and technician

TUG	Type of failure	Repair cost(IDR)	Source of cost	Technician
JLH-09	The cable connecting the pump to the panel broken	10,000,000	TUG revolving funds	technician who retired groundwater project officer
BDM-32	Replacement pipe and pump hose	8,000,000	TUG revolving funds	Groundwater Project technician
PKT-08	Pump, electric panel, irrigation network valve replacement	66,500,000	TUG revolving funds	Groundwater Project technician
TMB-59	Pump, electric panel replacement	40,000,000	Government	Groundwater Project technician
TTG-06	Electric panel, irrigation network valve replacement	Not known	Government	Groundwater Project technician
TTM-28	Electric panel, irrigation network valve replacement	Not known	Government	Groundwater Project technician

Use of irrigation

If measured by pump capacity, the use of water in each TUGs in 2019 is very low. In the dry months, the highest water demand occurs in September and October. During those months, the pumps only operated between 3 - 33% of the pump installed capacity (Table 5). This shows that the water requirements for irrigation in all TUGs samples are very low. In other words, water flowing through the irrigation system is intended to meet domestic needs rather than agriculture. This is not surprising, given that the delay in completing the irrigation system's physical development has led to agricultural development assistance activities not being met according to the SDIABKA Project plan. In addition, the regional agricultural extension program is not the focus of local government attention. In turn, the project's goal of developing intensive agriculture by commercializing high-value annual crops was not achieved (Andayani & Mulyati, 2021).

Table 5
Percentage of pump capacity used in TUGs samples in the peak month of operation in 2019

TUG	Peak pump operation			Pump capacity	
	Month	Hours	Day of month	Installed (hour)	Used (%)
JLH-09	September	218	30	660	33
BDM-32	September	52	30	660	8
PKT-08	Oktober	80	31	682	12
TMB-59	Oktober	240	31	682	35
TTG-06	Oktober	22	31	682	3
TTM-28	Oktober	22	31	682	3

Sustainability status

a) Sustainability of the physical-ecological dimension

The attributes (variables) used in the sustainability of the physical-ecological dimension include: availability of groundwater for the last 5 years; soil fertility conditions on agricultural land; access to groundwater utilization through pump wells; conversion of agricultural land use around pump wells; the role of TUGs in environmental conservation; pollution of garbage and waste in agricultural land; function of groundwater wells, serves to collect water from aquifers; function of the submersible pump with the driving engine (diesel engine, generator set, electricity from PLN); the function of the pump station building (pump house), which functions as a place for pump panels, machines, and other supporting tools; reservoir function, which functions as a tranquilizer/water reservoir before it is channeled into the carrier channel; the function of the conveyance channel, which can use the water pipe; and the function of the building divider into each box. Based on the results of the Rap-Ground Water Irrigation (GWI) analysis on the physical-ecological dimensions with MDS simulation, a sustainability index of 76.56 was obtained with a very sustainable status.

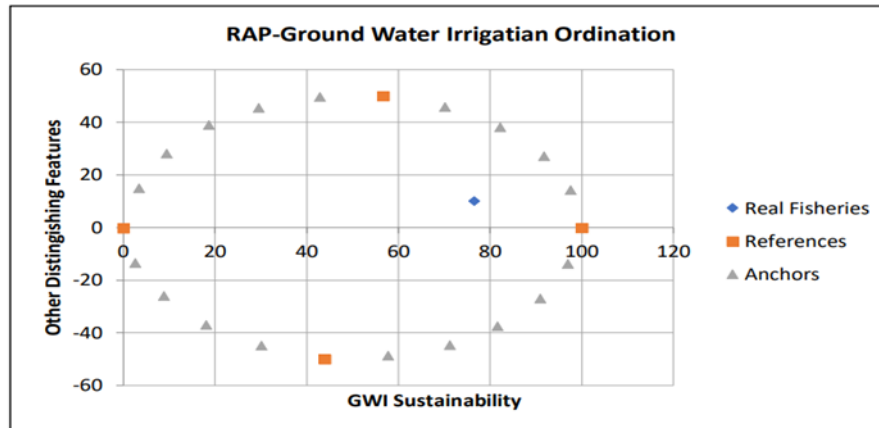


Figure 1. Value of the sustainability index of groundwater irrigation development in physical-ecological dimensions

The results of the leverage analysis show that the sensitive attribute is the availability of groundwater for the last 5 years. The attribute value is 2.00.

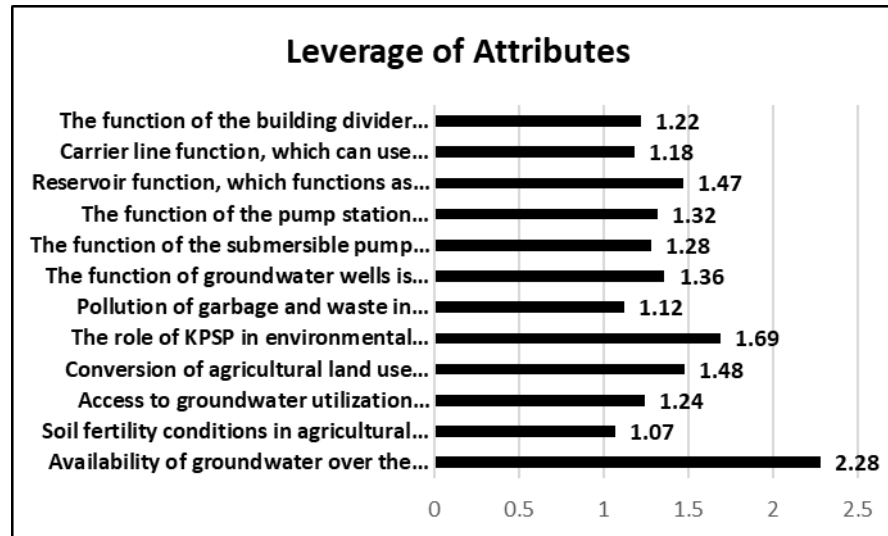


Figure 2. Results of leverage analysis on the ecological dimension

Groundwater is water that is found in layers of soil or rocks below the ground surface. The availability of groundwater is based on the type, distribution of rock and the lithology of the water-carrying layer. Groundwater availability is highly dependent on geological conditions. The main formation containing the aquifer is a quarter volcanic rock, as well as the altitude. The higher the place, generally the lower the groundwater content, because of the gravity to the lower area. Based on the geological formation (upper quarter volcanic with tuff lithology, breccia, agglomerates, and lahars) most of the Karangasem Regency area is a local aquifer that has high water potential, especially on the coast. The groundwater content is relatively large (10 lt/sec), which is located on the north coast of Kubu District, western Karangasem District, and part of Abang District (Badan Perencanaan Pembangunan Daerah Kabupaten Karangasem [Bappeda], 2020). The Buleleng Regency Long-Term Investment Program Plan for 2018-2022 also explains the potential for groundwater for irrigation in several sub-districts in Buleleng Regency, through exploration drilling and based on calculations, it is estimated that the effective groundwater source is recorded at 10,857 million m³. The utilization of groundwater is used for clean water (PDAM), for agricultural purposes and community drinking water (Badan Perencanaan Pembangunan Daerah Kabupaten Buleleng [Bappeda], 2020).

b) Economic dimensions of sustainability

Attributes (variables) used in the sustainability of the economic dimension include: pump well management costs, type of agricultural business, farming profits, fairness in profit sharing in TUGs, stability of agricultural prices, ease of market reach in selling agricultural products, and availability of funds for pump well maintenance. Based on the results of the Rap-Ground Water Irrigation (GWI) analysis on the economic dimension with the MDS simulation, a sustainability index of 52.80 was obtained with a fairly sustainable status.

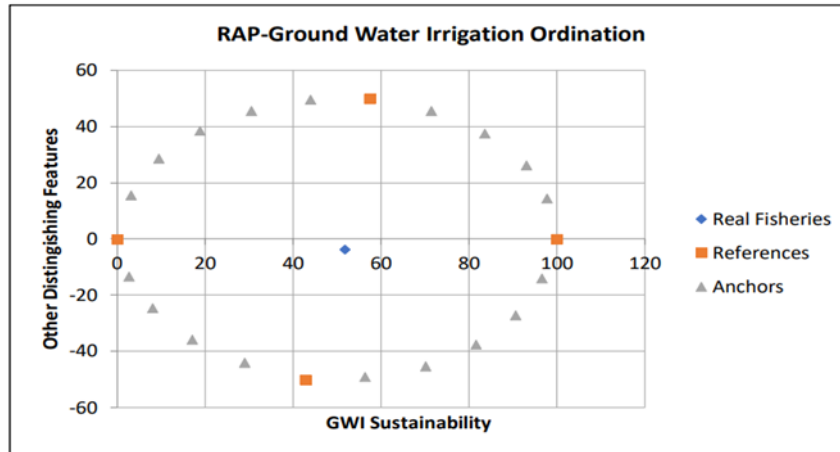


Figure 3. Value of the Sustainability Index of Groundwater Irrigation Development in Economic Dimensions

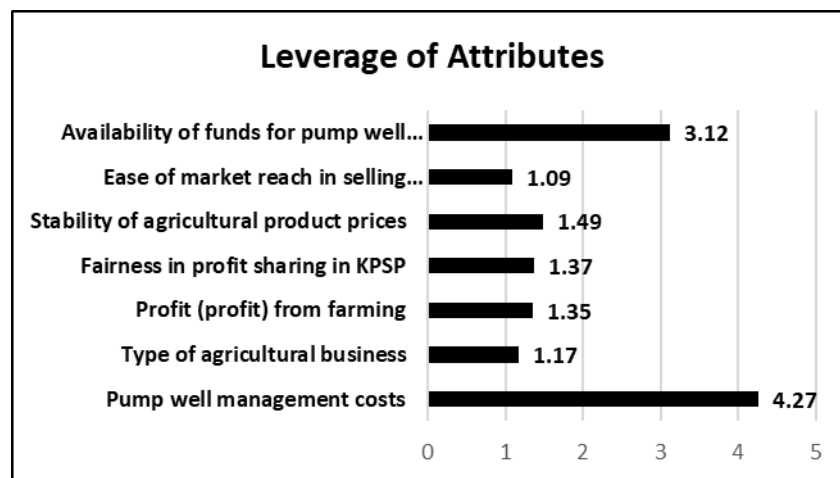


Figure 4. Results of leverage analysis on the economic dimension

In calculating the cost of irrigation network management, it is necessary to pay attention to the physical condition of irrigation infrastructure and facilities, because directly or indirectly it will greatly affect the operating and maintenance costs. The functional area directly affects the number of field personnel required (Roy et al., 2009; Bates, 2004). This means that the wider the functional area, the more number of field personnel needed. For groundwater irrigation, the operating and maintenance costs include the operation and maintenance of the pumping machine and the well. This condition causes the components of operating and maintenance costs to be higher, and the value per hectare will be higher. The operation and maintenance costs of irrigation networks are required every year, so the calculation used to determine the operating and maintenance costs per hectare is to divide the total management costs by the functional area or the area of irrigated land served (Gebregziabher et al., 2013; Global Water Partnership, 2012; Negara & Supriyadi, 2016; Sutrisno & Heryani, 2019).

In the development of groundwater irrigation, it is better to get subsidies from the government, including costs for groundwater exploration, design projects, drilling, construction of irrigation networks, provision of pumping machines and spare parts and so on including routine office costs and salaries of project employees. Direct benefits from this groundwater development project are received by water user farmers or TUGs. By obtaining irrigation services from P2AT, the intensity of planting can be increased and the alternative commodities it cultivates can increase, which in turn can increase the income of farmers who are members of the TUGs.

Research conducted by Joubert et al. (2016), proved that pump operation is carried out during the day or night with an operating time of 18 hours every day. The pump is operated during the day when solar energy can drive the pump, while at night or if solar energy is not able to drive the pump, it uses the existing water pump system (fueled by oil). Alabas (2013), explained that the development of a water-saving irrigation system was carried out by giving

water to the root areas of the plant (drip irrigation) for horticultural crops. In pump operation, the use of solar panels will minimize costs, especially in reducing the cost of fuel oil. During one growing season, the operating cost of using a solar-powered water pump is Rp. 1,350,000.00, far below the operating cost of using an oil pump of Rp. 26,550,000. This shows that operating costs can be reduced by up to 94.92% when using a solar-based water pump.

c) Sustainability of the socio-cultural dimension

Attributes (variables) used in the sustainability of the socio-cultural dimension include: the population growth rate around pumping wells, average level of education of farmers, activeness of cooperation activities in TUGs, level of employment in agriculture, frequency of conflicts related to the use of pumping wells, and the role of TUGs in preserving the values of Tri Hita Karana (THK). Based on the results of the Rap-Ground Water Irrigation (GWI) analysis of the socio-cultural dimension with the MDS simulation, a sustainability index of 78.93 was obtained with a very sustainable status.

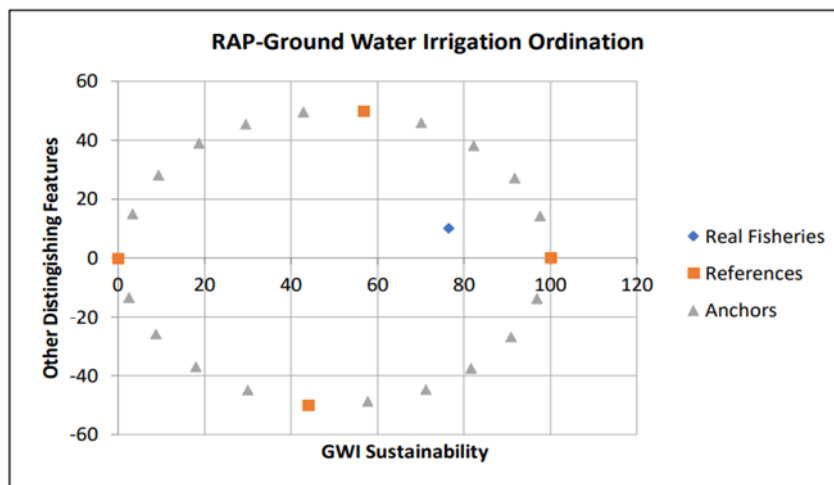


Figure 5. Sustainability Index Value of Groundwater Irrigation Development Socio-Cultural Dimension

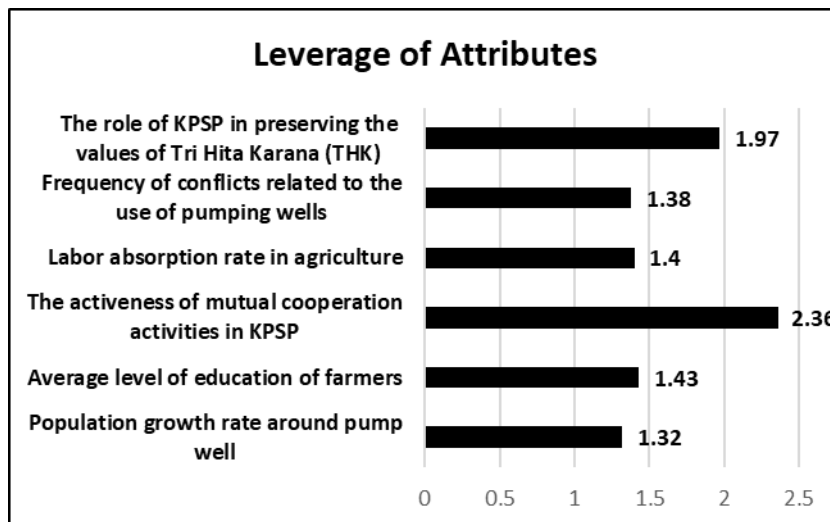


Figure 6. Results of leverage analysis on the socio-cultural dimension

Sedana (2010), explained that TUGs empowerment aims to create a TUGs institution that is autonomous, independent, rooted in the community, socio-economic, cultural, and environmentally friendly to improve the welfare of its members. Another objective of TUGs empowerment is that TUGs can provide convenience and

opportunities for its members to democratically form an organization/economic business unit at the farm level of their choice so that they can represent the interests of all members in dealing with external parties such as cooperatives, small businesses and others. Through this empowerment, it is hoped that an independent and strong group will be realized, known as 3 (three) steady, namely stable organization/management/administration; steady technical irrigation and agriculture; and financially stable. The activeness of members in cooperation is very necessary for realizing the sustainability of pump well management and the sustainability of groundwater management.

d) Sustainability of the infrastructure-technology dimension

The attributes (variables) used in the sustainability of the infrastructure-technology dimension include: the availability of agricultural infrastructure, farm road conditions, the use of technology in developing farming, the suitability of technology with the expected quality standards of agricultural products, and the use of pumping well technology. Based on the results of the Rap-Ground Water Irrigation (GWI) analysis of the infrastructure-technology dimension with the MDS simulation, a sustainability index of 68.73 was obtained with a fairly sustainable status.

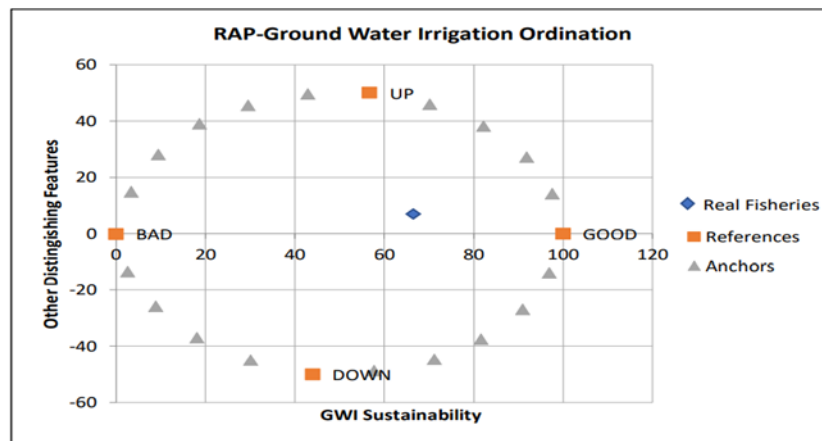


Figure 7. Value of the sustainability index of groundwater irrigation development in the infrastructure-technology dimension

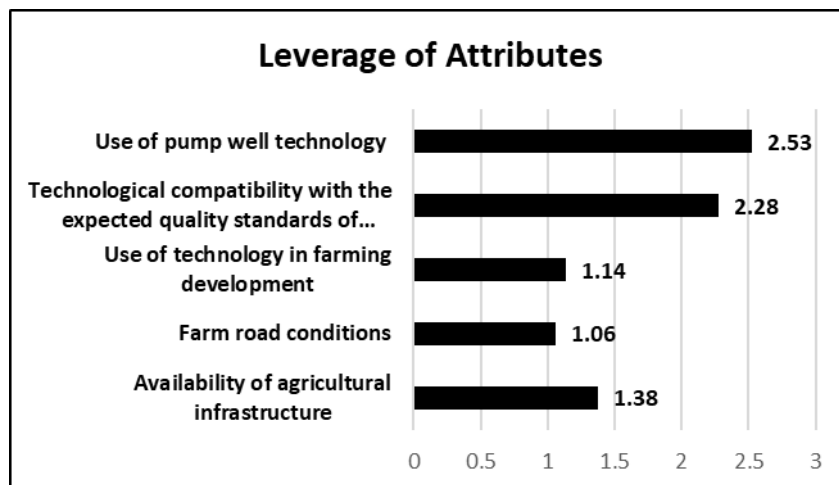


Figure 8. Results of leverage analysis on the infrastructure-technology dimension

The application of water-saving irrigation technology will also increase water productivity which is the ratio between the value of plant productivity and the value of irrigation water given in units of kg/m³ or tons/m³. In simple terms, it can be defined as a comparison between the output and the water input used (Bassi, 2020). Even though it is in an area with dry conditions, with optimal cropping patterns in the form of water-saving irrigation cultivation, water

productivity can be increased at least the same as when water conditions are sufficient so that the economic value of the water unit also increases (Montazar & Rahimikob, 2008; Rejekiingrum & Kartiwa, 2017; Bonita & Mardiyanto, 2015).

Efforts to increase irrigation water productivity through the application of water-saving irrigation technology are things that must be considered to ensure the sustainability of agricultural development in the future. Water-saving irrigation technology in the form of drip irrigation will deliver water droplets to the ground at a low flow rate (2-20 liters/hour) through small diameter plastic pipes equipped with small holes called droppers or emitters/drippers. The most suitable crops using a drip irrigation system are row crops (vegetables, soft fruit), trees and vines where one or more droppers can be provided for each plant. Drip irrigation is highly recommended only for crops of high economic value so that it can offset the high investment or initial capital costs (Hani, 2015). The suitability of technology with cost-effectiveness is certainly expected to produce agricultural products with good quality standards and quality.

e) Sustainability of the institutional dimension

The existence of a pump irrigation system in Indonesia cannot be separated from the development of irrigation in general which is empirically dominated by a weir irrigation system (gravity). Although the total area consisting of the entire pump irrigation system when compared to the gravity irrigation system is very small, its role is very important, even in some cases a strategic breakthrough (Dincer, 2000; Berardi, 2013).

Several attributes (variables) used in the sustainability of the institutional dimension include: the implementation of regulations on groundwater irrigation management, conflict resolution procedures and mechanisms, government support in groundwater irrigation management, availability of capital institutions for KPSPs, and coordination between KP2SPs and the government.

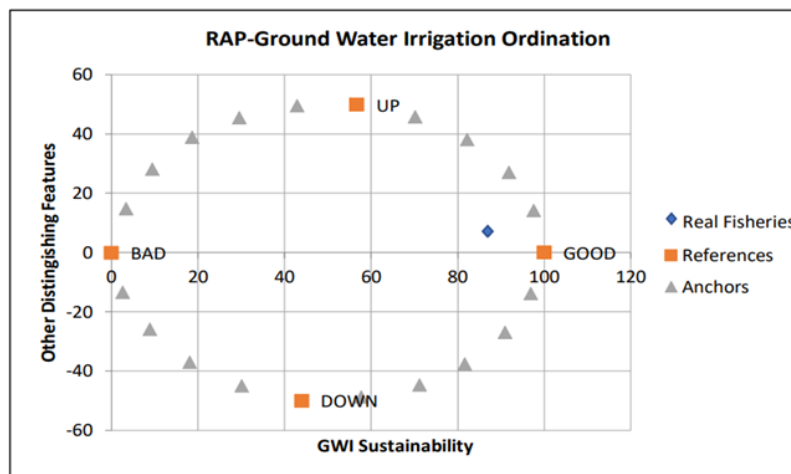


Figure 9. Value of the sustainability index of groundwater irrigation development in institutional dimensions

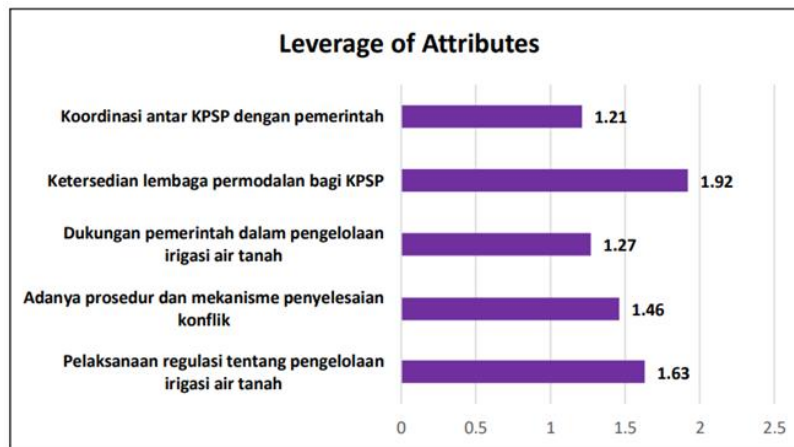


Figure 10. Results of leverage analysis on the institutional dimension

The results of the leverage analysis show that a sensitive attribute is the availability of capital institutions for KPSPs so that in the future KPSPs can produce and develop seasonal and annual crops of high value and competitiveness. This condition will later be able to help farmers who are members of TUGs to manage the operating and maintenance costs of groundwater irrigation networks and pumping wells independently and sustainably. One example of a capital institution that is needed is a Micro-Finance Institution (MFI).

Conclusions

After more than 10 years of the "Sustainable Agricultural Irrigation Development Project in Buleleng and Karangasem (SDIABKA)", the groundwater irrigation system that was developed through the assistance of the European Economic Community (MEE) has not demonstrated steady sustainability in all TUGs. Sustainability in 3 of the 6 samples seemed worrying, which was reflected by the reduced number of group members, the low achievement of the revolving fund accumulation target, and the dependence on the government for the operation and maintenance of the irrigation system. The development of intensive agriculture with annual crops of economic value does not seem to show results as planned. The use of irrigation water is very low which is reflected in the low operating capacity of the pump installed.

Judging from the sustainability status of groundwater irrigation development, the physical-ecological, socio-cultural, and institutional dimensions have a very sustainable status. The economic and infrastructure-technology dimensions are classified as quite sustainable. There are several sensitive variables (that need to be improved) including: the availability of groundwater for the last 5 years, availability of funds for pump well maintenance, pump well management costs, active cooperation in TUGs in groundwater irrigation management, use of pump well technology, technological suitability with the expected quality standards of agricultural products, and the availability of capital institutions for TUGs.

Recommendations

Triggered by the availability of groundwater irrigation, the development of sweet potatoes, elephant grass, bananas, and papayas have been able to increase the role of agriculture in the total income of farmers' households, but the potential is still very large for farmers to exploit. Farmers are no longer struggling with climate risks but pest disease and price risks are still the biggest risks in farming in the project area. The risk-averse attitude of small farmers versus low-risk off-farm employment opportunities makes it difficult for farmers to adopt other intensive crops such as melons, chillies, long beans, and other horticultural crops. Therefore, techniques that can mitigate pest-disease risks and costs must continue to be sought and developed in the project area.

Following Law Number 12 of 1992 concerning Plant Cultivation Systems, the implementation of plant protection against pests and diseases must be practical, effective, economical, sociological and safe for the environment called Integrated Pest Control (IPM). Suitable control does not suppress each other and does not limit each other in a control system that follows the local farming pattern. In this case, pests (plant-disturbing organisms, OPT) if they can be managed properly, economic losses can be avoided and bad side effects can be minimized by combining various control techniques such as technical, mechanical, biological and chemical culture as an alternative the latter. TUGs

will be strong and independent to implement this if they can manage the sustainability of groundwater irrigation and farming patterns that are supported by strong capital institutions so that they can produce agricultural products at valuable and highly competitive prices.

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