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Utilizing Bamboo Cavity as an Appropriate Technology for Shallow Groundwater Conversion

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Abstract*— Since the early 1970s, many farmers on the west coast of Indonesia have used groundwater to irrigate their agricultural land. Groundwater used is mainly done for rice, corn, and other secondary crops. As a result, the groundwater level in the area has experienced significant degradation and has also been followed by an increase in groundwater salinity. The government's suggestion to make artificial recharge with composter pipes or with "*biopori*" technology is considered difficult for farmers since they cannot afford to buy PVC pipes as their main ingredient. The challenge gave birth to our innovation to utilize local materials in the form of bamboo for artificial infiltration tools, which we call "bamboo-cavity." The three advantages of filling with "bamboo-cavity" are: (1) the ingredients are cheap and easy to obtain in the area of people's agriculture; (2) pollution-free because the material is without chemicals; and (3) easy to install because there is no need for soil drilling, where the bamboo is directly put in a hand hummer. This initial research was carried out with two objectives, namely: (1) Finding out the effect of "cavities" on the recovery of degraded groundwater; and (2) Knowing the effect of the number of inflection points on the rate of recovery of groundwater. The research was carried out by applying nine variations in the number of infiltration points, on agricultural land with topsoil characteristics that have low permeability. The results of the study provide an overview of the effectiveness of cavities as a means of enhancing, namely: (1) the effect of the number of cavities on increasing groundwater levels is very significant. The results of field observations found that the total increase in groundwater level in wells with the formation of 8 cavities reached 75%, compared to the increase in groundwater level in the control wells and the more installed cavities, the higher the increase in groundwater that occurs; (2) The test wells with the highest value of additive effectiveness are wells with a number of cavities between 56 and 64 points of infiltration, i.e., the recharge effectiveness reaches 3.74.

***Keywords*—shallow groundwater; artificial recharge; bamboo-cavity; groundwater degradation; recharge effectiveness.**

I. Introduction

The use of groundwater to meet the irrigation water needs of farmers in Indonesia has begun to bloom since the 2000s [1]. This followed several years of groundwater exploitation by farmers in Indonesia. As a result of the intensive use of groundwater for the needs of their plants for many years, it gradually causes degradation of groundwater conditions. The vulnerability of groundwater conditions in the territory of Indonesia is getting higher because it is quite close to the coast so that it is very potential to trigger seawater intrusion rapidly with large volumes [2], [3]. The groundwater crisis has been experienced in various countries which exploit groundwater more than the land infiltration capacity [4]. The groundwater crisis is not only in groundwater degradation but also in the increased salinity of groundwater that produces groundwater cannot be used [5]. The deterioration in the condition of groundwater both in quantity and quality needs to be sought to be overcome through regulation, based on the right policies whose preparation involves various government agencies as well as through technical engineering facilities [6]. Groundwater degradation can cause multiple impacts, in the form of seawater intrusion processes, and/or decreases in soil fertility or increase air temperature or disrupt the climate cycle, as well as various other impacts [7].

In Law of Indonesia Number 32 in 2009 concerning Protection and Management of the Environment, in article 3 it is affirmed that the objectives of environmental protection and management include; to control the utilization of natural resources wisely, realize sustainable development, and anticipate global ecological issues [8]. Groundwater is one of the natural resources that need to be guaranteed for its availability and sustainability to realize sustainable development. In the Law of Indonesia Number 37 in 2014 concerning Soil and Water Conservation, until now, there are no implementing regulations [9]. The only operational policy from the government related to the current groundwater conservation effort is the Ministerial regulation of energy and human resources Number 15 in 2012 concerning Savings of Groundwater Use.

According to Chandrakanth et al. [7] that groundwater management, in general, is an effort to manage the linkages between various determinants of groundwater resources, such as vegetation, recharge areas, infiltration patterns, and human resources that are located and activities in the groundwater basin area. Groundwater basins are an area that is limited by hydrogeological boundaries, which become the location of all hydrogeological events such as the process of filling, flowing, and groundwater release taking place [10]. There are two types of treatment of nature are developing in human culture [11] as follows:

- Culture of subduing nature (frontier), which places itself not as a subordinate of nature surrounding so that they view nature as a source that is prepared to be exploited by humans.
- Culture is integrated with nature (eco-friendly), which views that all interactions between humans and the surrounding environment will cause "reciprocal influence" between humans and the surrounding environment, so that humans cannot escape as one of the sub-ordinates of the surrounding environment, and see that damage to nature and the environment is damage that also afflicts itself.

The terminology of groundwater conservation is an effort to protect and maintain the presence, condition, and environment of groundwater to maintain continuity of availability in adequate quantity and quality of functions and benefits to meet the needs of living creatures, both present and upcoming [12]. Water conservation cannot be separated from soil conservation so that both are often referred to together to become soil and water conservation [13]. This implies that soil conservation activities will have an effect not only on improving land conditions but also on improving the condition of the water resources, and vice versa.

Initially, groundwater conservation was defined as storing water and using it for productive purposes later. This concept is called supply conservation. Subsequent developments in conservation lead more to the reduction or efficiency of water use and are known as conservation side needs [13]. The type of groundwater depends on its existence and its location, in general, can be categorized into two types, namely; shallow groundwater, namely groundwater that is close to the ground; and deep groundwater, namely groundwater, which is located far below the surface of the ground [14]. According to Sophocleous et al. [4], groundwater flows within the aquifer can be distinguished in confined aquifers and unconfined aquifers.

Water balance needs to be maintained, and the existence of groundwater as one of the hydraulic components on the planet is essential. According to Arun et al. [4], the use of water for various human needs theoretically will not reduce the volume of water present on this earth. Still, improper use of water will result in a shift in the existence of water types. The mainland water balance will change along with the environmental changes that occur, which are generally caused by human actions. The volume of groundwater can be reduced due to the difficulty of the infiltration process because various buildings made by humans cover the surface of the land, and this will increase the volume of surface water in the form of floodwater [15].

Based on the conditional analysis as described above, we examine the possibility of applying an artificial filling system that can be applied to shallow groundwater recharge, which has surface soil characteristics that have small permeability using natural (not synthetic) materials, which will not have an impact on environmental pollution.

II. Materials And Method

A. Material

There are several techniques for implementing groundwater filling with artificial recharge [16], such as:

1) Water injection techniques (injection technique): This technique is usually applied to filling in the deep aquifer, which is usually a compressed aquifer.

2) Composter pipe technique: a technique combined with composting waste. So, that surface water is more comfortable to infiltrate through the composter pipe.

3) Biopori techniques: a groundwater recharge technique with a layer of topsoil with low permeability is quite thin; this is because the biopori system cannot be made deeper as in the Composter Pipe system.

4) Infiltration pipe technique: developed by Darwis et al. [5], which can be used to penetrate deeper layers of low permeability (depth can reach 6 m).

The use of bamboo as an artificial recharge tool, which aims to maintain the sustainability of groundwater, will provide various benefits, including:

- Bamboo material as a means of enhancing, cheap, and easy to obtain.
- Installation of bamboo filling equipment is straightforward enough with a punch, and no drilling is needed.
- It can be placed in a sloping position into the ground, making it possible to get a more extensive cross-section of infiltration.
- The most important thing is that the gadgets that enter the soil layer will not cause environmental pollution in the soil.

The results of this study can directly provide multi-player effects, both the environmental impact and the community and local government (social-economic effect).

The benefits of this research on the environment, namely:

- It can guarantee the continuity of the existence of freshwater ground so that the balance of the ecosystem in the region will be maintained;
- Can avoid environmental pollution due to not using gadgets from synthetic materials such as plastic or cement materials.
- It can develop human resources that love the environment, with farmers who have understood the importance of maintaining environmental balance.

The benefits of this research result to the community (farmers), among others;

- It can apply inexpensive and easy to carry out technology.

- The existence of groundwater they need will be guaranteed and able to support their farming sustainably.
- Fertility and moisture content on agricultural land will be maintained because groundwater supply is always sufficient.
- Can increase the income and welfare of farmers, with the opportunity for them to produce throughout the season;

The special benefit of the results of this research is for the Regional Government to provide input to formulate regulations on the use of environmentally sound groundwater as well as a cheap groundwater conservation step, so as to guarantee the sustainability of the existence and utilization of groundwater in the area.

B. Method

This research is research and development in the form of experimental field research, which will examine and develop alternative uses of bamboo, as a means of enhancing shallow groundwater conservation efforts. The study was carried out in the Barombong district of Gowa regency, South Sulawesi, Indonesia, where farmers in rice fields and secondary crops in the area used groundwater as irrigation water during the dry season. The research location must move every year because it must be avoided by the influence of the installers installed in the previous year, but the implementation of the 3-year study will continue to be carried out within the Biringala Village, Barombong District, Gowa Regency. The infill point formation at the 9-unit test well is observed, as illustrated below:

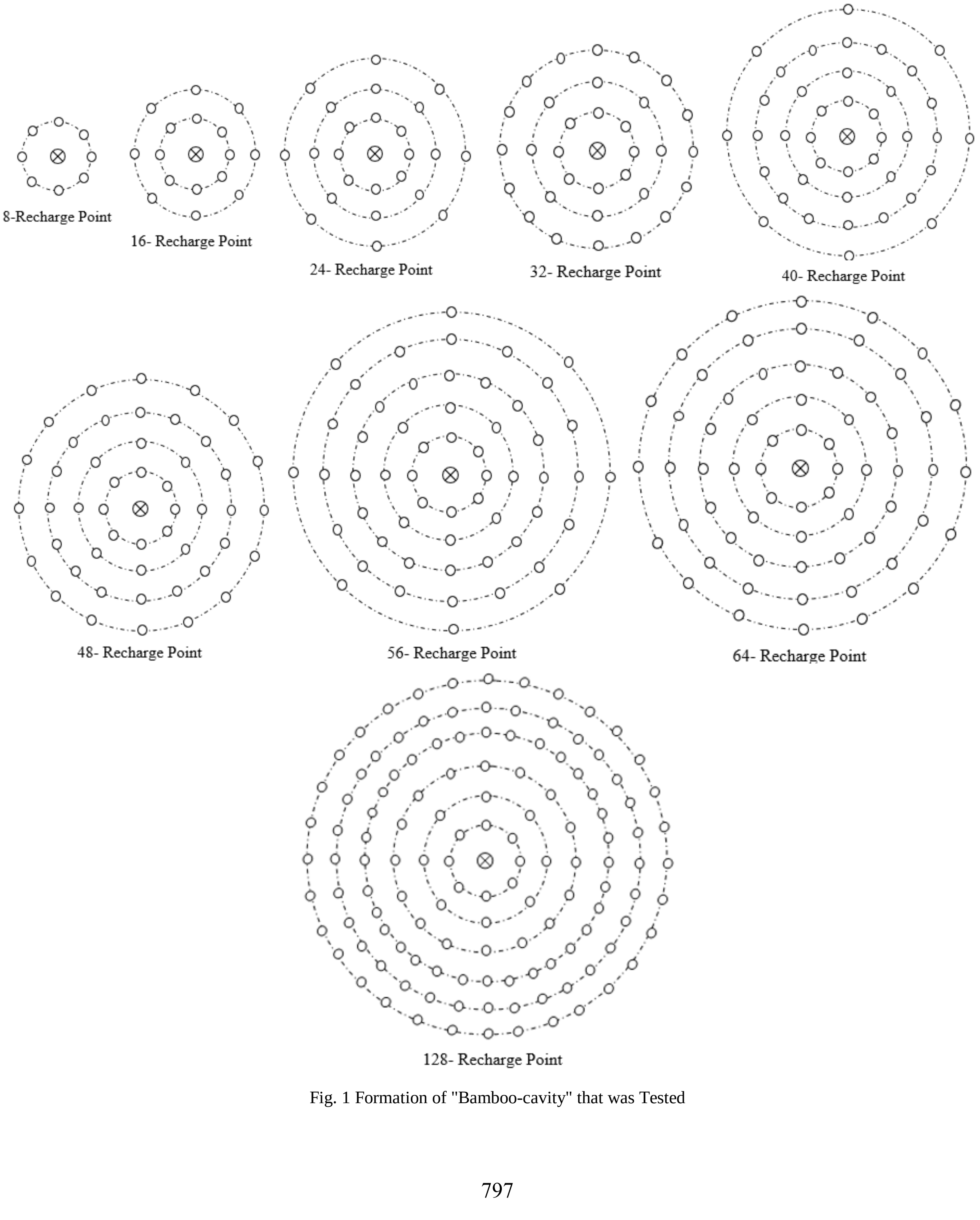

Fig. 1 Formation of "Bamboo-cavity" that was Tested

Concerning the Figure 1, it is essential to describe the variables and measure indicators in this study. The independent variables in this study are as follows:
Independent variable:

- X: Number of points to add "bamboo cavity"
- Amount of Recharge Point is X = 8; 16; 24; 32; 40; 48; 56; 64, and 128 of Test Well (9 formation);
- Added bamboo length (h) = 1.5m;
- Addition point (s) = 5m;
- Control well = 1 unit;
- Test well = 9 units.

The dependent variable is Y= Groundwater Benefits. The measured indicator is the increase of the groundwater level in a test well. To better understand the research variables, it is necessary to state the operational definition that has become a reference in this study, including:

- Groundwater Benefits is the volume of groundwater that fills the aquifer. The recharge volume is measured by increasing the groundwater level in the test well, which is observed every time there is a filling.
- The number of points to add the "bamboo cavity" is the number of filters installed in a formation surrounding the well of the test well in the application of the "bamboo cavity." In this experiment, the depth (h) and distance of the infiltration point (s) are controlled (h = 1.5m and s = 5m).
- The depth of the embankment of the "bamboo cavity" is the depth of the embankment installed in one formation surrounding the test well in the application of the "bamboo cavity."
- The density of the "bamboo cavity" is a density of adhesives installed in a formation surrounding the well of the test well in the application of the "bamboo cavity."

III. Result and Discussion

A. Results

1) No Recharge Point: From field observations carried out on the nine test wells and control well, starting from the 1st (first) rain until the 18th rain in 2017, a Figure is generated, as shown in the following Figure 2.

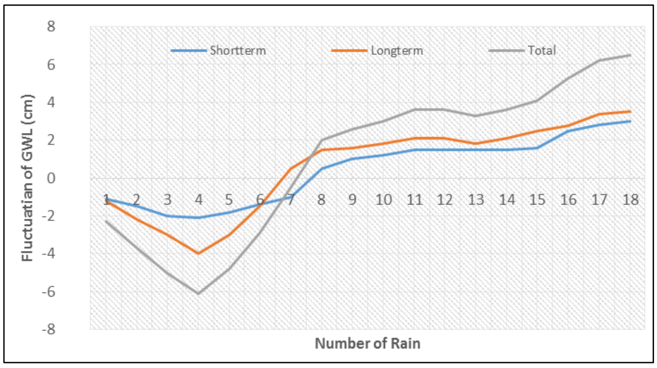

Fig. 2 Fluctuation in Groundwater Level on Control Well (No Recharge Point)

Capillary shock phenomena that occur in control well look shallower, but the recovery time of the groundwater level is slower.

2) Recharge Point: In 8-recharge point test wells (Test Well - 01); Capillary shock occurs deeper than control well, but recovery of the groundwater level is slightly faster.

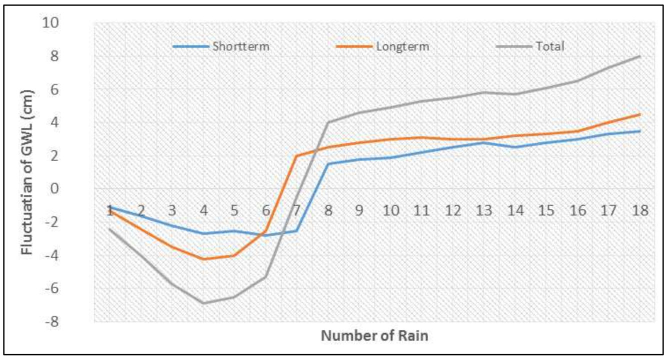

Fig. 3 Fluctuation in Groundwater Level on Test Well-01 (8-Recharge Point)

3) 16-Recharge Point): In the 16-recharge point test well - 02); Capillary shock occurs deeper than Test Well - 01, but the recovery time of the groundwater level is faster.

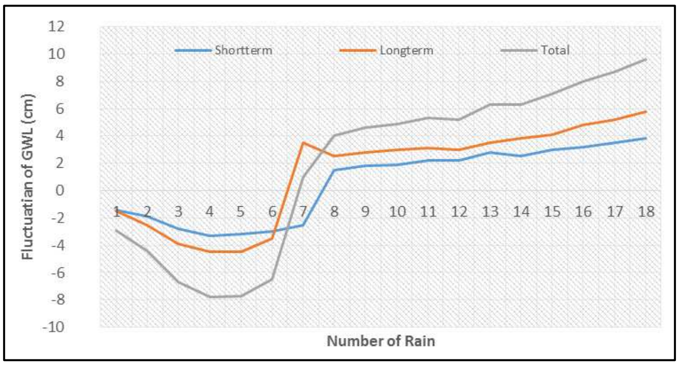

Fig. 4 Fluctuation in Groundwater Level on Test Well-02 (16-Recharge Point)

4) 24-Recharge Point: In test wells with 24-recharge points (Test Well - 03), Capillary shock occurs deeper than Test Well - 02, but recovery time of groundwater level is faster, and an increase in groundwater level is higher for each number of rains.

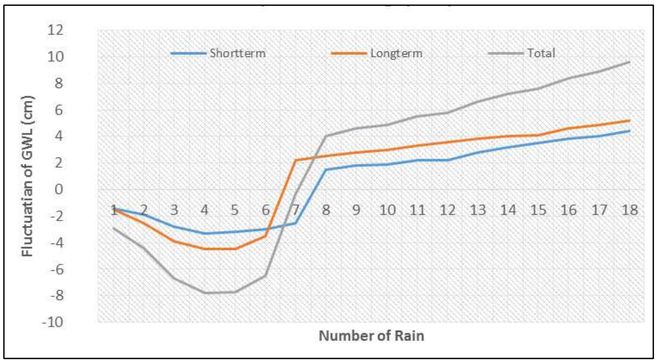

Fig. 5 Fluctuation in Groundwater Level on Test Well-03 (24-Recharge Point)

5) 32-Recharge Point: In test wells with 32-recharge points (Test Well - 04); Capillary shock occurs deeper than Test Well - 03, but the recovery time of groundwater level is faster, and the increase in groundwater level is even higher for each number of rains.

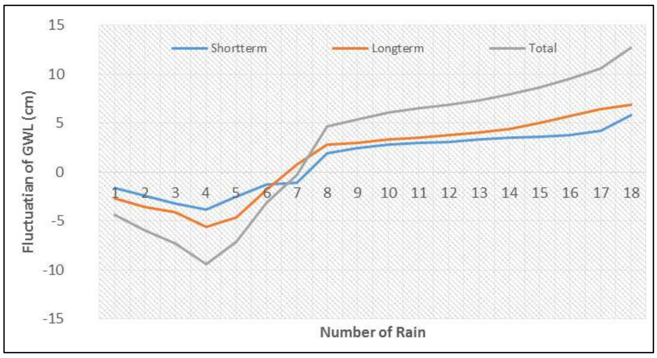

Fig. 6 Fluctuation in Groundwater Level on Test Well-04 (32-Recharge Point)

6) 40-Recharge Point: In test wells with 40-recharge points (Test Well - 05); Capillary shock occurs deeper than the Test Well - 04, but the recovery time of groundwater level is faster, and the increase in groundwater level is higher for each number of rains.

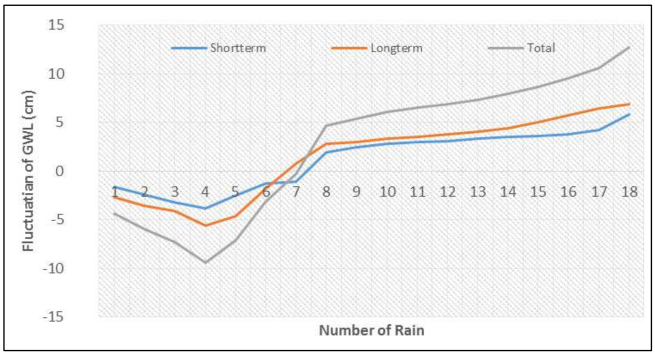

Fig. 7 Fluctuation in Groundwater Level on Test Well-05 (40-Recharge Point)

7) 48-Recharge Point: In test wells with 48-recharge points (Test Well - 06); Capillary shock occurs deeper than the Well Test-05, but the recovery time of the groundwater level is faster, and the increase in groundwater level is higher for each number of rains.

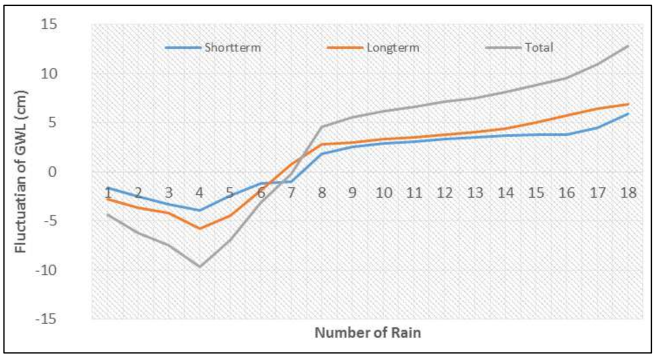

Fig. 8 Fluctuation in Groundwater Level on Test Well-06 (48-Recharge Point)

8) 56-Recharge Point: In test wells with 56-recharge points (Test Well - 07), Capillary shock occurs deeper than the Well Test - 06, but the recovery time of the groundwater level is faster. And the increase in groundwater level is higher but significant for each number of rains.

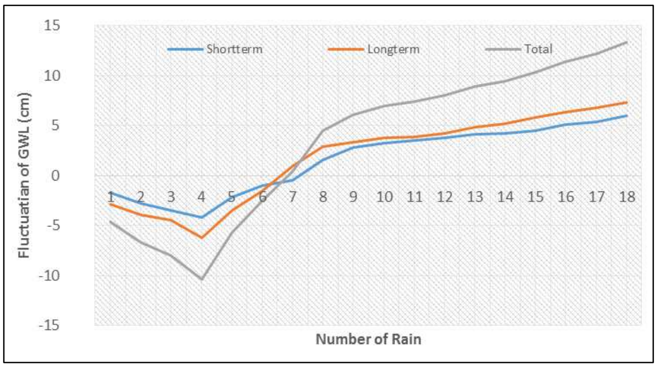

Fig. 9 Fluctuation in Groundwater Level on Test Well-07 (56-Recharge Point)

9) 64-Recharge Point: In 64-recharge point test wells (Test Well - 08); Capillary shock occurs deeper than the Well Test - 07, but the recovery time of the groundwater level is faster. And the increase in groundwater level is higher, but still significant for each number of rains.

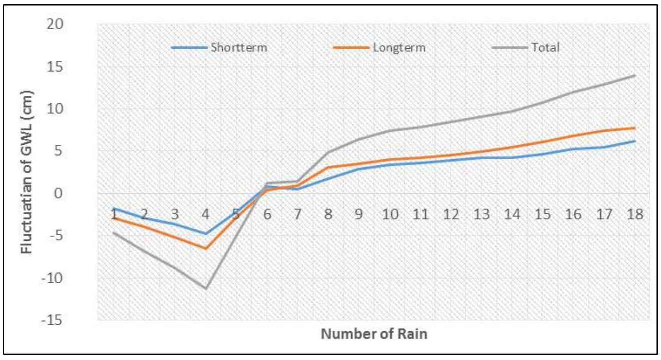

Fig. 10 Fluctuation in Groundwater Level on Test Well-08 (64-Recharge Point)

10) 128-Recharge Point: In test wells with 128-recharge points (Test Well - 09), Capillary shock occurs deeper than Test Well - 08, but recovery time from the groundwater level is faster. The increase in groundwater level is slightly higher, but the difference.

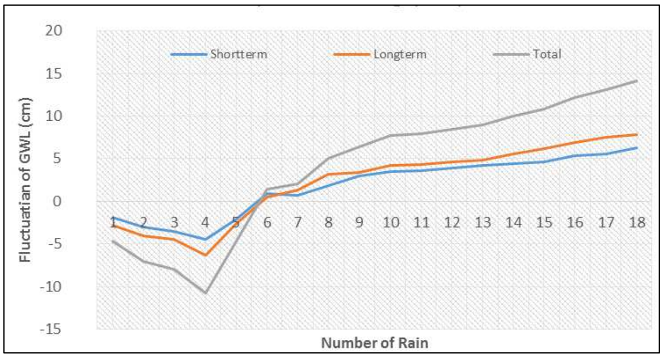

Fig. 11 Fluctuation in Groundwater Level on Test Well-09 (128-Recharge Point)

11) The increase of groundwater level each well based on the number of recharge points: From Figure-11, it can be seen that the effective affix of the results is a formation with some bamboo cavities between 48 to 64 points. But overall, the use of bamboo cavities as a gadget is quite significant in the filling of shallow groundwater in unconfined aquifers.

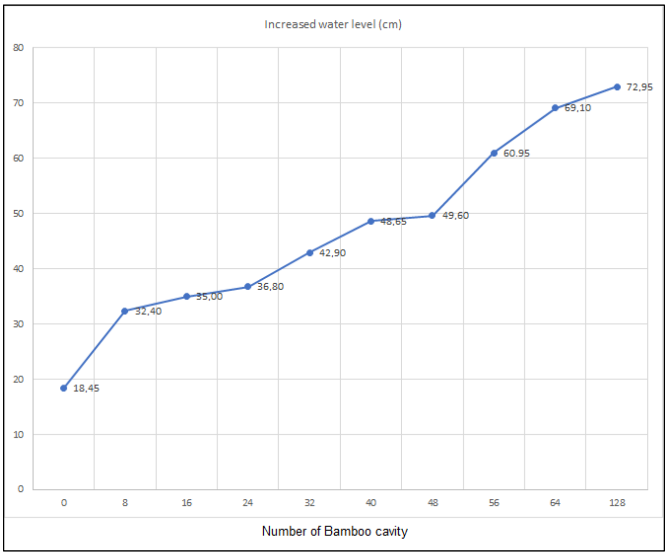

Fig. 12 The increase of groundwater level each well based on the number of recharge points.

B. Discussion

From the Figure of observations of groundwater fluctuations in each test well and control well, several things that can be used as discussion material are needed, both for the application of the results of this study and further development needs of this research, including:

1) Groundwater Fluctuations in Control Wells (Figure-1); Readings of groundwater fluctuations in control wells, carried out together with readings on all testing wells, before the rain, after rain until 5 hours after the rain stops. Readings produced from control wells will be a reference and a comparison of the readings provided on the nine test wells observed. In Figure 1, groundwater fluctuations that occur in control wells are relatively small and run slowly. This is because the topsoil has a small permeability. Besides, groundwater fluctuations show that changes in groundwater levels for long-terms are always greater than changes in groundwater levels for short-terms.

2) Groundwater Fluctuations in 9-Test Well (Figure-2 to Figure-10): Of the nine formation points that are applied to the test wells, all of them exhibit the same symptoms, namely that the existence of bamboo (cavity) enhancers significantly influences the process of filling water into the soil. The number of cavities affects the level and duration of capillary shock (the phenomenon of the onset of the rainy season, which is decreasing groundwater due to increased pore pressure). Likewise, the effect of the number of infiltration points on the level and time of recovery of groundwater looks very significant. Still, in this case, the number of recharge points is effective with the number of points of increment between 48 and 64 bamboos.

3) Effect of the number of bamboos on the total increase in groundwater level (Figure-11): The effect of bamboo-cavity on the increase in groundwater level shown in Figure 12 is very significant. Even with the minimum number of cavities (8-point) already able to increase recharge effectiveness by 75%, when compared to the increase in groundwater level in control wells. It seems that groundwater does not increase in a linear scale with the addition of the number of cavities. The number of cavities that have high effectiveness on increasing groundwater recharge is in the range of 48 to 64 infiltration points. This can be seen in the ratio of increasing groundwater between 64 wells and 128 cavities, which only ranges from 5.57%. Thus, the use of too much recharge in one test well does not significantly affect the increase in groundwater level

IV. Conclusion

The effect of bamboo-cavity on the increase in groundwater level is very significant, even with the minimum number of cavities (8-point) can increase the recharge effectiveness by 75%, when compared to the increase in groundwater level in control well. It seems that groundwater does not increase in a linear scale with the addition of the number of cavities. The number of cavities that have high effectiveness on increasing groundwater recharge is in the range of 48 to 64 infiltration points. This can be seen in the ratio of increasing groundwater between 64 wells and 128 cavities, which only ranges from 5.57%. Thus, the use of too much recharge in one test well does not significantly affect the increase in the groundwater level.

The number of infiltration points (bamboo-cavity) has a direct effect on the level of groundwater decline at the beginning of the rainy season. In the test wells with some infiltration points of 56 bamboo cavities, the formation has the most influence on the decreasing level of groundwater shown in the phenomenon of capillary shock. Furthermore, the number of cavities (inflection point) also influences the duration of the capillary shock symptoms in groundwater, where the more infiltration points are applied, the faster the symptoms stop. In another Figure, it can also be seen that the deadline for the rainy period which causes capillary shock, ranges from the 8th rain for wells with small cavities, and reaches the 6th rain for wells with the application of many cavities.

Based on a review of the research methods and experience and various obstacles faced by the research team in the field, several recommendations can be put forward. Further research is needed to determine the various variables of bamboo gadgets, as well as the effectiveness of their application to various existing soil conditions. Various parameters of the bamboo cavity require in-depth studies such as the influence of the depth of the filler, the diameter of the filler, the spacing of the reinforcement, and the type of bamboo that is used as a gadget. In addition, further research also needs to pay attention to soil characteristics, as well as matters related to the effectiveness of the application of cavities as a means of enhancing various types and conditions of surface soils. These parameters need to be revealed for the perfection of groundwater conservation technology with the bamboo cavity.

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