The application of parallel wells to support the use of groundwater for sustainable irrigation

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Abstract. The use of groundwater as a source of irrigation is one alternative in meeting water needs of plants. Using groundwater for irrigation requires a high cost because of the discharge that can be taken is limited. In addition, the use of large groundwater can cause environmental damage and social conflict. To minimize costs, maintain quality of the environment and to prevent social conflicts, it is necessary to innovate in the groundwater taking system. The study was conducted with an innovation of using parallel wells. Performance is measured by comparing parallel wells with a single well. The results showed that the use of parallel wells to meet the water needs of rice plants and increase the pump discharge up to 100%. In addition, parallel wells can reduce the influence radius of taking of groundwater compared to single well so as to prevent social conflict. Thus, the use of parallel wells can support the achievement of the use of groundwater for sustainable irrigation.

1. Introduction

Groundwater becomes one of the alternatives in the fulfillment of the water needs of rice plants, especially in the dry season. This is supported by the availability of about 25% of the total freshwater available [1]. In the use of ground water for irrigation, it must be done with caution because the amount of water taken is very large. Impacts that can be generated by long-term groundwater harvesting are environmental degradation such as land subsidence [2], costly losses due to decreased pumping capacity due to groundwater impairment [3, 4], and can caused to social conflict between groundwater users due to competition of resource use [5]. Therefore, this study aims to meet the needs of crop water by using sustainable groundwater irrigation.

2. Materials and methods

The study was conducted by testing the method of groundwater extraction using the parallel well method (diameter of pipe 2 and 3 in) and comparing it with conventional method (single well with 2 in diameter pipe). The required data was a debit data generated by each pumping method. The tool used are the pump unit, stopwatch and container of water reservoir. Some software was used in data processing such as excel add-ins such as VBA and solver.

The method of groundwater table fluctuations is one of the methods to estimate the groundwater recharge rate [6], used to estimate groundwater table decrease due to groundwater extraction. The decrease of groundwater table as one of the causes of land subsidence was determined by using 2 dimensional groundwater flow equation [7] shown in equation 1.

$$K.h\left(\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}\right)=S_y\frac{\partial h}{\partial t}\pm R(x,y,t) \qquad (1)$$

where:

K	= hydraulic conductivity (m/s)
h	= head (m)
x,y	= coordinate position (m)
t	= time (s)
Sy	= Safe yield (dimensionless)
R	= Recharge or discharge (m^3/s)

The above equations were solved numerically by finite different methods using an implicit approach (*forward finite difference*) in which each space is evaluated for the next time (*t*+1) with the Crank-Nicolson approach [8]. This method has been applied in the investigation of groundwater level [9] with a coefficient of determination of 0.85.

The use of parallel wells was expected to minimize pump operational cost through increasing pump discharge so that the area of irrigation was increased. The area of irrigation depends on the discharge generated by the pump unit, calculated using the equation:

$$A = 0.1\frac{Q}{W_R} \tag{2}$$

where:

A	= area of irrigation (ha)
Q	= discharge (m^3/d)
W_R	= water requirement (mm/d)
0.1	= conversion m^3 to mm*ha.

3. Results and Discussion

The results obtained were the change of groundwater level caused by groundwater extraction. In this case, the use of a single well to irrigate a certain rice field area requires many pump units. The use of several pumping units resulted in a decrease in the groundwater level at depth until the suction capacity of the pump suction depth became widespread. This was shown in the following figure:

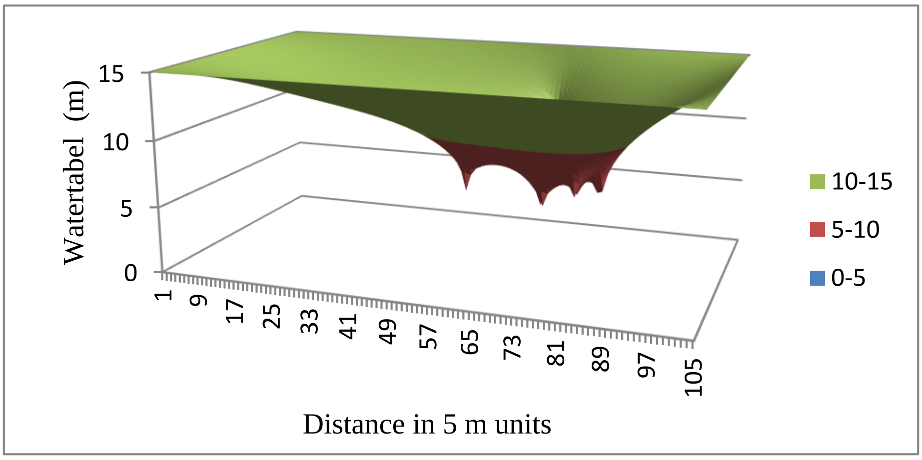

Figure 1. Groundwater profile using single well.

Figure 1 shows that groundwater harvesting with a single well leads to widespread groundwater degradation in the shooting area. If this condition occurs over a long period of time it can cause a land subsidence [2]. In contrast to the use of parallel wells, this method can increase the discharge rate for each pump unit so that the groundwater retrieval point location is reduced. Thus, the decrease of groundwater level does not occur widely as shown in figure 2 below:

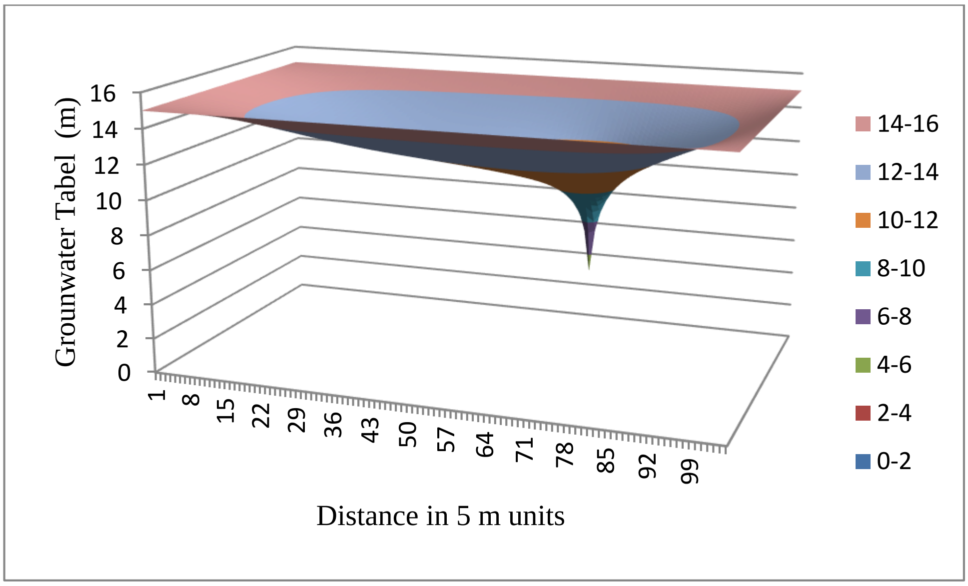

Figure 2. Groundwater profile applying parallel wells.

Because groundwater level reduction was not widespread, the pumping capacity relatively stable because the pump unit was not affected. Another advantage of using parallel wells was that the discharge obtained for one pump unit increases to 100%. The following is the increase of pump discharge data as a result of the use of parallel wells compared to conventional methods.

Table 1. Increased discharge of pumps using parallel wells

Treatment	Discharge			
	average (l/s)	Stdev	Average (m^3/d)	Stdev
Single well, pump 2"	5.27	0.18	455.33	14.22
Parallel wells, pump 2"	6.71	0.15	579.74	12.86
Parallel wells, pump 3"	10.74	0.46	928.11	39.33

Increased discharge for one pump unit can reduce the pumping cost because the cost depends on the price of each lifting of water for a certain volume (m-ha) [10]. These costs include fuel costs, pump unit maintenance costs and operator fees. A large pump discharge reduces costs due to the length of pump operation to get a certain volume of water shorter so that fuel, maintenance costs and operator costs become less.

In addition, the increased discharge of the pump will increase the area of irrigation covered by one pump unit and the decrease of groundwater level for a certain distance becomes small. Thus, the chances of social conflict occur from competition between groundwater users can be eliminated. The area of irrigation for one pump unit using a parallel well increases up to 100% when compared to conventional methods. The amount of irrigation area was calculated with the assumption that the water requirement of rice plant at the research location is 4.60 mm / day [11].

Table 2. Increasing the area of irrigation by using parallel wells

Treatment	Irrigation cover area	Increased area to single wells
	(ha)	(%)
Single well, pump 2"	9.90	-
Parallel wells, pump 2"	12.60	27.27
Parallel wells, pump 3"	20.18	103.84

With increasing irrigation area, irrigation cost can be reduced due to the length of pump operation reduced so as to reduce fuel cost, pump unit maintenance cost and operator cost. Thus, the use of parallel wells can reduce the impact of groundwater use for irrigation on environmental damage, reduce pump operating costs and reduce the impact on social conflicts so that sustainable groundwater irrigation.

4. Conclusion

The application of parallel wells supports the sustainable use of groundwater for irrigation through increased pump discharge thus reducing pump operational costs, reducing environmental impacts through reducing impact areas, and preventing social conflicts through reducing conflict between resource users.

References

[1] Black P E 1996 *Watershed Hydrology*. 2nd edition (New York: Ann Arbor Press, Inc) p 460
[2] Li C, Tang X and Ma T 2006 Land subsidence caused by groundwater exploitation in the Hangzhou-Jiaxing-Huzhou Plain, China *Hydrogeology J.* **14** (8) 1652–1665
[3] Medellín-Azuara J, MacEwan D, Howitt R E, Koruakos G, Dogrul E C, Brush C F, Kadir T N, Harter T, Melton F and Lund J R 2015 Hydro-economic analysis of groundwater pumping for irrigated agriculture in California’s Central Valley, USA *Hydrogeology J.* **23** (6) 1205–1216
[4] Bunu M Z 1999 Groundwater management perspectives for Borno and Yobe states, Nigeria *J. of Env. Hydrology* **7** (19) 1-10
[5] Shrestha S 2017 The contested common pool resource: Ground water use in urban Kathmandu, Nepal *The Geographic. J. of Nepal* **10** 153-166
[6] de Silva R P 2004 Spatial Variability of Groundwater Recharge - I. Is it really variable? *J. of Spatial Hydro.* **4** (1) 1-18
[7] Trescott P C and Larson S P 1977 Solution of three-dimensional groundwater flow equations using the strongly implicit procedure *J. of Hydro.* **35** 49 - 60
[8] Carnahan B, Luther H A and Wilkes J O 1990 *Applied Numerical Methods* (Malabar, Florida: Rober E. Krieger Publ. Co) p 604
[9] Suhardi, Setiawan B I, Pawitan H and Waspodo R S B 2011 Optimization of groundwater utilization for irrigation in wajo district, south sulawesi province of indonesia (in Bahasa) *Jurnal Irigasi* **6** (2) 80-89
[10] Kovacs K and West G 2016 The influence of groundwater depletion from irrigated agriculture on the tradeoffs between ecosystem services and economic returns *PLoS ONE* **11** (12) 1-22
[11] Suhardi 2008 *Groundwater Management Model for Irrigation with Single and Multiple Pump Operation. Case: Data Sub-Watershed, Wajo District, South Sulawesi* (in Bahasa). *Dissertation* (Bogor: Bogor Agricultural University)