Agro-well Development and its Impact on Groundwater Table Depletion in Tank Cascades in the Dry Zone of Sri Lanka

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Abstract
With the inadequacy of rainfall and irrigated water in small tank systems in the Dry Zone of Sri Lanka to maintain the agricultural activities throughout the year, farmers as well as researchers explore the possibility of extracting groundwater. Consequently, the construction of “Agro-wells” in low lying areas especially in tank cascades to tap the shallow groundwater to cultivate perennial as well as seasonal crops throughout the year is practiced. The use of “groundwater” through Agro-wells has been very rapid in recent years, which has been discussed among the research community. Some of them warned that there will be serious damages to groundwater table. Therefore, to investigate the real situation, current study was conducted in 2013/2014, covering three tank cascades in the Dry Zone of Sri Lanka. The study was planned to compare the status and the behavior of the groundwater table between different Agro-well density cascades. Accordingly, 44 Agro-wells were observed monthly in order to measure the depth of the water table for 13 months. Elevation points of Agro-wells were taken from a GPS receiver. An analysis was based on GIS maps and “Kriging Interpolation Method” that was used to assume the un-sample points to create groundwater elevation contours. Results revealed that no outstanding difference of groundwater level depletion in high Agro-well density cascades in the dry season.

Key Words: Agro-wells, Tank Cascades, Groundwater Table, GIS maps.
1. Background

The inadequacy of rainfall and irrigated water are the main barriers for dry zone farmers in Sri Lanka to maintain agricultural activities throughout the year. The use of “groundwater” through Agro-wells for agricultural purposes was studied long before its rapid adoption in recent years. In the 1950s, Farmer (1951) pointed out the possibility of introducing Agro-wells to the dry zone of Sri Lanka, considering the geological similarity of the region to some parts of south India, where the use of Agro-wells was already popular. Later, Sirimanna (1952), Panabokke (1959), Fernando (1973), and Madduma Bandara (1973, 1977) studied the possibility of using groundwater for agriculture in the hard rock areas of the Dry Zone of Sri Lanka (Kikuchi et al. 2003).

The Anuradhapura Dry Zone Agricultural Project (ADZAP) was implemented over a five year period from 1981, to the establishment of a well developed farming system in the project area, including the restoration of minor tanks and practicing and introducing Agricultural wells or Agro-wells (Jayasena, 1991). Pathmarajah (2002) pointed out that, the rate of construction of Agro-wells to use shallow groundwater has accelerated with the interventions of the Agricultural Development Authority (ADA) and the Provincial Councils since 1989. “The National Agro-well Programme” was the one of key intervention for popularization of Agro-wells. In addition, various Non-governmental Organizations such as the International Fund for Agricultural Development (IFAD), Asian Development Bank (ADB), and a few local Non Governmental Organizations including Isuru Foundation also extend subsidies and subsidized loans for the construction of Agro-wells (Kikuchi et al. 2003). However, according to the Perera’s (2010) estimation, there are about 120,000 Agro-wells in the Island.

The average diameter of Agro-wells in the study area was 5.6 m and average depth was 7.3 m while the average depth to bed rock was 6.4 m. The current study has shown that the average ground water level fluctuates between 3.6 m – 6.9 m in the dry months (July–September) and average groundwater level was 5.3 m. Further about 90% of Agro-wells have at least 2.0 m water depth in the most dry months (July–September) in the area. More than 85% of Agro-wells have been using annually. However, the diffusion of Agro-wells has been very rapid in the vicinity of small tanks in the dry zone due to easy access to the shallow aquifers.

Figure 1: Small Tank & Agro-well

Source: Field Observation 2012
Small tanks are not individual units but a connected series of tanks. Madduma Bandara (1985) defined this unit as “Tank Cascade Systems” and the tank cascade systems are lay out in small drainage basins.

**Figure 2: A Tank Cascade**

The highest Agro-well density cascades are found in Malwathu Oya, Daduru Oya, Mee Oya and Yan Oya basins in the dry zone. According to Dharmasena (2002), the small tanks cascade systems interacting with hydro-ecological features and contribute to overall sustainability of the system, including maintaining the ground water level closer to the land surface, even in the dry season.

According to a groundwater level study, conducted in the Dambagaswewa cascade in the Yan Oya basin by Perera (2001), revealed that 50% of Agro-wells have been established within ½ km from the small tanks. Further, Agro-well water is being fluctuated consequently to the water fluctuations of small tanks as well as depend on the rainfall pattern. But the decreasing trend of Agro-well water level within the dry season was accelerated with the starting of Agro-well based cultivation in the month of May. Dharmesena (2002), argued that the construction of small tank system in the dry zone was a major effort to maintain the ground water level closer to the land surface, and un-controlled Agro-well development might damage to the ground water level.

Senaratna’s (1996) study, conducted on 50 cascades in Anuradhapura district, has shown that the optimum number of Agro-wells that could be safely accommodated within these 50 cascades is not more than 3,600 due to water table issue. With these results and Dharmesena’s (2002) argument, Panabokke (2002) revealed that the number of Agro-wells in tank cascades had already exceeded the upper limit. Further, according to Rajendra, Ariyabandu and Aheeyar (2004), the shallow aquifers in the local valley alluvium and the exploitation of ground water, using Agro-wells in some micro catchments, may lead to a net depletion of the water table. As reported by Shah (1993) and Morris et al. (1997), in India and Bangladesh, where the diffusion of Agro-wells began much earlier than Sri Lanka, and the reducing of the groundwater table due to over pumping has been reported in many places (Kikuchi et al. 2003).

In this situation, there was a general opinion that Agro-well farming causes low ground water level or accelerates the groundwater depletion in the dry season in high Agro-well density areas.
However, still there is no clear scientific evidence to record the serious adverse effects on groundwater table, due to exceeding of wells in tank cascades in Sri Lanka. Therefore this study aimed to fill this research gap by examining the ground water table fluctuations due to ground water extraction through Agro-wells, using different tank cascades where Agro-well density is different.

2. Study area

Due to the technical requirements of this study it was necessary to select nearby cascades. Therefore, three nearby cascades were selected in Malwathu Oya Basin where Agro-well density was High (Periyakulama / 22 per sq km), Medium (Konwewa / 14.8 per sq km) and Low (Halmillawewa / 5.4 per sq km). Roughly these cascades represent similar resource background except the Agro-well density.

Background of selected cascades:

i. All three cascades were geomorphologically separated.
ii. Equal depth to bedrock (within a small range).
iii. Equal slope percentage of cascades.
iv. Equal amount of groundwater extraction for domestic purposes.
v. Equal land use types.
vi. Similar cropping pattern and water issuing periods from small tanks.
vii. Similarities of Agro-wells, crops and land area.
viii. Only the Agro-well density is different. That mean, ground water extraction is different.

In addition to that the following assumptions were also made:

i. Rainfall amount for these 3 cascades during the test period is same (due to nearby cascades).
ii. Evapotranspiration rate of these cascades is same (nearby cascades).
iii. Equal porosity and permeability condition of the soil
iv. Agro-well diameter of all wells were within a small range

Rainfall and groundwater level fluctuations were observed of these cascades to realize the background knowledge.

Graph 1: Groundwater level fluctuations with rainfall

Source: Field data collection 2012-2014
In general, the groundwater table shows a downward trend from January to October due to the low rainfall, groundwater loss from evaporation, seepage, percolation as well as the groundwater extraction for human needs. Further, groundwater level fluctuation depends on the amount of rainfall and tank water level behavior of tank cascades. However this study was conducted under the situation of very similar rainfall conditions for the nearby cascades, very same cropping and water issuing periods from small tanks.

3. Methodology

Groundwater data was collected from fairly distributed 44 Agro-wells in these cascades for the current study. The sample Agro-wells were selected using ½ km grid and each Agro-well has been selected by the random sampling method within each grid. The water table was measured monthly using a measuring tape from the ground level. According to a mutual understanding with relevant farmers, before pumping-out the water (at least after 3 days of the last pumping) the water table measurements were taken, on 15th of each month. Monthly measurements of the water table depth of Agro-wells were recorded from January 2013 to January 2014. Elevation points of Agro-wells were taken from a GPS receiver.

Map 1: Sample Agro-wells for groundwater table measurement
(3 tank cascades in Malwathu Oya Basin)

Figure 3: The ½ km grid for selecting fairly distribution of wells

Source: Geo Eye 1 satellite images -2012
Figure 4: Measuring of the groundwater level by a field assistant

Source: Field study 2013

Based on the groundwater level data, the “groundwater table maps” (below the ground level) have been produced to ascertain whether the water table depletion is comparatively high in high Agro-well density cascades. This groundwater table behavior was identified using GIS maps analysis based on Geo Eye–1 Satellite images. The “Kriging Interpolation Method” was used to assume the un-sample points to create groundwater elevation contours. Accordingly, separate maps of “water table depth- below ground level” covering the climatic year were prepared, for these three cascades.

4. Results and Discussions

In January (during the north-east monsoon rainy season) the groundwater table maps have been showed groundwater table near to the ground level (0-0.5 m) or equal to the ground level at every place in all cascades.
Map 2: Depth of the groundwater table from the ground level –January 2013

Source: - Geo Eye 1 satellite images-2012 & Field data-2013

With the beginning of the Agro-well based cultivation (during a year) in April or May, tank based irrigation agriculture was over and farmers have started to pump water (groundwater extraction) from Agro-wells. No considerable difference of groundwater levels existed within the three cascades. Groundwater levels of all cascades were between 0.5 m to 2.0 m.
After two months (July 2013), during the groundwater extraction through Agro-wells, there was no difference in groundwater levels of both types of cascades. All water table values were recorded in between 2.0 m and 3.0 m.
Even in the end of the groundwater extraction period from Agro-wells (October), there was no significant difference of the groundwater table between high and low Agro-well density cascades. All water level values were reordered between 3.5 m -5.0 m in all cascades.
If the groundwater extraction is more powerful than the normal water table decline in the dry period, Periyakulama (high Agro-well density cascade) should be more drier or the groundwater table should be lower level than in other cascades. But during this experiment, could not be identify such a situation. Further, groundwater table has declined proportionately even in the low Agro-well density tank cascade (Halmillawewa) in the dry season. This situation has proven that the groundwater table depletion in the dry season in high Agro-well density cascades did not have a significant impact of groundwater extraction through Agro-wells. The groundwater table has automatically declined with or without groundwater extraction through Agro-wells.

The main factor for the groundwater fluctuations was the rainfall pattern. Therefore there is no outstanding evidence to prove that groundwater extraction may accelerate the groundwater table depletion in tank cascades in study area.

Not only that, by the month of January 2014 (during the North East monsoon rainy period), groundwater table in all cascades (including high Agro-well density cascade), has been increased up to the ground level as usually (Map 6). Accordingly it is clear that the groundwater fluctuation mainly depended on the rainfall pattern and seasonal drying.
5. Conclusion

The aim of the study was identifying the impacts on groundwater table due to Agro-well development in tank cascades in the Dry Zone of Sri Lanka. Accordingly, it was identified the differences of water table depletion using “groundwater table maps” (below ground level) within a year. This study has revealed that the groundwater table has normally declined with or without groundwater extraction through Agro-wells. This means, that the main factor for the groundwater fluctuations in all tank cascades was the rainfall pattern. Therefore no significant evidence exists to prove that groundwater extraction has accelerated the groundwater table depletion in tank cascades at the current Agro-well density condition in the area.

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