Volume-7
Issue- II
December-2022
Rajarata University Journal
ISSN: 2362-0080
www.ruj.ac.lk/journals/

Category: Research Article

Agro-well based Agricultural Systems: An Approach to Groundwater Use in Ancient Tank Cascade Systems of Sri Lanka

Muditha Prasannajith Perera

Department of Geography, University of Peradeniya

ARTICLE DETAILS

Article History

Published Online: *14th August 2024*

Keywords
Tank cascades, Agro-wells, Groundwater, Pumping tests, Hydrological changes

***Corresponding Author**
Email: mudithpras@gmail.com

ABSTRACT

Ancient tank cascade systems in Sri Lanka have been exemplified as the historical vestige of ancient tank irrigation technology. These systems have been operating as surface water bodies in connection with ecological features and social interactions since the BC Period. With the increasing demand for more food and more income in recent decades, the system operators tried to find an additional cultivation season from the same resource base. The answer was extracting available shallow groundwater resources by constructing Agro-wells as a new strategy within the system. With the gradual expansion of this new trend from 1989, significant outcomes could be seen in these ancient irrigation tank cascades. The objective of this study was to examine the hydrological changes and outcomes of this recent intervention of Agro-wells. Six sample irrigation tank cascades covering two river basins were used for data collection. Half recovery pumping tests, water level measurements, floral surveys, and satellite images were used to collect the data. Well-specific capacity and floral analysis were used to analyze the data. With this new intervention of Agro-wells, floral diversity, and stratification have been increased. However, it has not very much affected the groundwater availability and the water table in the system. This study reveals that groundwater use through Agro-wells in irrigation tank cascades has been a recent trend in the dry zone of Sri Lanka.

1. Introduction

Agro-well is a large-diameter well especially constructed for groundwater-based agricultural purposes. In the 1980s Agro-well based agriculture was popular in South Asian countries including Sri Lanka. Although the construction of Agro-wells started in 1989 in the dry zone of Sri Lanka, excavation of Agro-wells was accelerated between 1991-1995, with the arrival of excavating machines to the area in addition to the intervention of the Agricultural Development Authority and the Provincial Councils. However, currently, there are about 150,000 Agro wells mostly in tank cascades in the dry zone of Sri Lanka.

Before the 1980s entire dry zone of Sri Lankan agriculture depended on the surface water resources of irrigation tanks. About 95% of these tanks in the dry zone are laid out as cascade systems. A tank cascade system can be identified as a “Connected Series of tanks with its micro catchments and command areas, organized within a small valley”. This cascade behavior of small tanks would help to conserve rainwater in the entire small basin and there is an ability to re-use the tank water after releasing it to the downstream paddy area due to the chain-type tank and paddy field system. Further, Dharmesena [1] explained that one of the real facts is that the construction of a small tank system as cascades in the dry zone was one of the major efforts to maintain the groundwater level.

However, the use of “Groundwater” for agricultural purposes has been studied in Sri Lanka since the 1950s. B.H. Farmer explored the potential of using groundwater in the dry zone of Sri Lanka in 1951, considering the geological similarity of the region to some parts of South India, where the use of Agro-wells was already popular (Kikuchi et al. 2003) [2]. Then several researchers including, Panabokke [3], and Madduma Bandara [4] also revealed the possibility of using groundwater even in the dry season, in these regions.

Dharmasena and Goodwill [5], explained the availability of the top weathered zones in the lowland parts of the small drainage basins, which can store the infiltrated rainwater. This weathered bedrock is the aquifer which serves as the groundwater for Agro-well irrigation. Sakthivadivel [6] and Dharmasena [7] explained that these micro basins act as regolith aquifer zones. Further, Panabokke, [8], recognized the most dominant area of tank cascade systems, as a separate groundwater zone in Sri Lanka, by naming it "Shallow regolith aquifers in tank cascade areas".

The above context and the emerging scientific studies showed the path to finding shallow groundwater to perform agricultural activities in the dry season in addition to the surface water use of the irrigation tanks in the rainy season. Thus farmers excavated large-diameter wells (Agro-wells) in their lowlands in the vicinity of small tanks, with or without institutional support. Thus, several tank cascade systems, as well as a large extent of lowlands in small inland valleys, in the dry zone of Sri Lanka, were converted into the "Agro-well lands" with an Agro-well. Most of the farmers are engaging in shallow groundwater-based Agro-well cultivation, after engaging in paddy cultivation under the irrigation tank systems. Currently, most of the river basins that are significant to the tank cascade systems, including MalwathuOya, Yan Oya, DaduruOya, Kala Oya, and Kirindi Oya, have become prominent areas for Agro-well land development.

The objective of this study is to examine the current context of the use of groundwater through Agro-wells in ancient irrigation tank cascades, from different perspectives. The nature of the Agro-well expansion and, its impact on the groundwater behavior in the vicinity of tanks, will be further analyzed.

2. Material and Methods

2.1 Study Area

North Central Dry Zone of Sri Lanka was selected for the study considering the significance of Agro-well development as well as the availability of ancient irrigation tank cascades. Within that, 6 sample tank cascades were randomly selected in the Yan Oya basin and MalwathuOya basin, to examine the ground-level reality. The soils of the area are imperfectly drained reddish-brown earth and a mixture of low humic gley soils, alluvial soils, and red-yellow latosols. According to Mapa's soil classification relevant to Sri Lanka [9], the dominant soil group is the Madawachchiya-Aluthwewa-Divulwewa-Hurathgama-Kahatagasdigiliya Association. Soil texture varies from sandy loam to clay loam. An average vertical section of a well wall shows A and B soil profiles and Decomposition Parent Material (soil profile - C) up to a maximum depth of 6.5 m to the bedrock. The geomorphologic settings of the area are micro-level basins that consist of small tanks as cascades. Generally, 0.7 to 2.0 slope percentages have been identified, in all cascades. Nearly 90% of the dry zone parts including this area are covered by metamorphic crystalline rocks, called "hard rocks" de Silva, [10]. The main rocks are charnockitic gneiss and quartz feldspar garnet granulite. The annual rainfall fluctuates between 1100 mm and 1400 mm and 30 years' mean annual rainfall was 1340 mm for the study area. The annual average range of temperature of the area is between 25° C - 30° C. The rainy season is from November to January (the North-East Monsoon period) and the dry season is from August to October.

2.2 Methodology

To observe the land use changes in this irrigation tank cascade area, aerial photographs and Geo Eye 1 - 2012 - 0.5m high-resolution exclusive satellite images, were used. Further, field verifications through direct observations were conducted to check the information's accuracy. Tank water levels were measured monthly within a climatic year, at the sluice point for necessary analysis. The upper tank and the lower tank of each tank cascade were used for measuring the tank water level and water depth from the spill level was recorded at the sluice point. Then, the groundwater table fluctuations of selected Agro-wells and the tank water level were measured weekly covering a climatic year. Groundwater data were collected from fairly distributed 44 selected Agro-wells using the stratified random sampling method, in a cascade cluster consisting of 3 irrigation tank cascades (Figure:1). Three cascades were selected to represent the Agro-well density as high (Periyakulama), medium (Konwewa), and low (Halmillawewa) to represent the general situation of the dry zone of Sri Lanka.

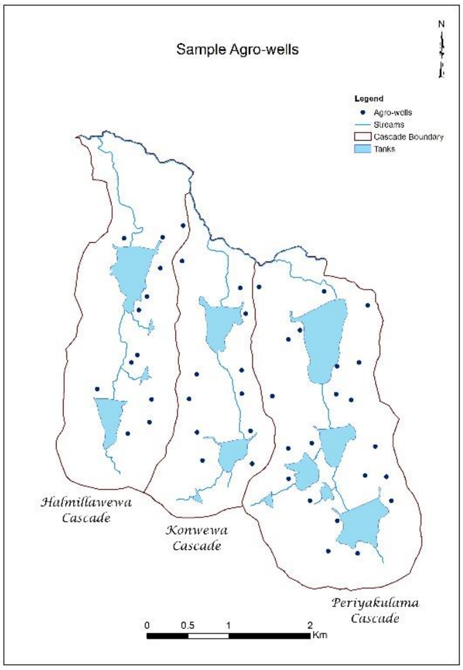

Figure 1: Sample Agro-wells in three tank cascades

To examine the impact on groundwater availability due to extraction from Agro-wells, a comparative study was conducted between high Agro-well density cascades and low Agro-well density cascades using 6 Agro-wells from each cascade. For this purpose, an index termed the "Half Recovery Time" (T1/2) could be derived from basic relationships of good hydrology Dharmasena, [11]. It is defined as the time taken to recover half the depth pumped out from a well. The index was found to be independent at the initial depth of water, the considered time gap during the period of recuperation, and the depth of water extraction, but it only varies with the aquifer characteristics and well diameter [12].

The Half Recovery Time (T1/2) can be given by:

$$T1/2 = \frac{0.54\ D2}{K}$$

Where, D = well diameter K = well specific capacity

Then, the well-specific capacity (K) values (m3/hr) relevant to the different periods during the Agro-well water extraction, were compared with two cascades. Then the well-specific capacity was computed using the same formula as;

$$K = \frac{0.54\ D2}{T1/2}$$

Where, D = well diameter, T1/2 = half recovery time, and 0.54= constant value of the aquifer characteristics for the cascade environments.

To obtain the data on Agro-well construction in tank reservations of the study area, satellite images were observed and followed by field verifications. Further, Three focus group discussions were conducted with 10-12 outstanding farmers for each cascade representing the lower, middle, and upper parts of the tank cascades, to extract the economic and production data. Arc Map GIS software and a few Microsoft Office software were used for necessary identifications, calculations, and correlations.

3. Results and Discussion

3.1 The Status of Agro-wells and Relevant Land Units.

After excavating an Agro-well using an excavating machine, the walls of the well were lined with bricks and cement. Accordingly, 68% of the Agro-wells in the study area were “lined Agro-wells”. They were well-planned and standard according to the guidelines of the Agricultural Department of Sri Lanka. The remaining 32% of wells were “unlined Agro-wells” which are not lined with bricks and cement. According to the farmers, the unlined Agro-wells need to be de-silted once in 3-5 years for maintenance purposes.

Figure 2: A Lined Agro-well in the Belikulama tank cascade

Source: Field study, 2015

This study showed that there were only 102 Agro-wells in 1994 which increased to 404 in 2012. The amounts of the Agro-wells or Agro-well density of each cascade in the study area were different. The range of the Agro-well density was 1.1 to 22 per sq. km. (Table 1). That has been dependent on the farmer's motivation level for Agro-well farming, economic ability, institutional subsidy programs with political support, and accessibility of excavating machines. However, elephant migrations, as well as terrorist problems during the past period, were the significant barrios to the Agro-well construction in the area.

Table 1: Agro-well availability in each tank cascades

Tank cascade	Extent km^2	Number of small tanks	Number of Agro-wells	Agro-well density per/ km^2
Periyakulama	6.4	6	141	22
Kon wewa	3.5	3	52	14.8
Halmillawewa	4.6	4	25	5.4
Belikulama	8.1	4	154	19
Dambagaswewa	3.1	3	24	7.7
Rambe wewa	7.5	6	8	1.1

Source: Field Study, 2015

The average diameter of Agro-wells in the study area was 5.6 m, the average depth was 7.3 m and the average depth to bedrock was 6.4 m. The observed depth was slightly higher while the diameter was lower than the depth of 7 m (22 f) and a diameter of 6 m (18.5 ft) suggested by the Govt. of SL [13]. The Agro-well agricultural lands in the area were a large range of land (0.2 ha to 1.4 ha) and the average land area was 0.4 ha. (Table 2).

Table 2: Nature of Agro-wells in the study area

Agro-well Characteristic	Minimum	Maximum	Average
Diameter (m)	4.7	7.6	5.6
Depth (m)	5.4	9.1	7.3
Depth to the water table in most dry months (m) (July- September)	3.6	6.9	5.3
Depth to bedrock (m)	5.4	9.0	6.4
Agro-well based land (ha)	0.2	1.4	0.4

Source: Field Study, 2015

3.2 Cropping pattern under the Agro-wells.

In the beginning, farmers try to cultivate annual crops including vegetable varieties, Chilies, and B Onion. Most probably farmers are expanding the annual cropland, and cultivating under the Agro-well water within the entire land belonging to them. The reason was that 60% of farmers dramatically included perennial crops such as Coconut and Mango in addition to the seasonal crops under the Agro-well water [14]. Then, with the development of the tree canopy of the perennial crops, they are moving to another part of the same land for annual crops. Further, the land tenure of these Agro-well base lands was a complex situation. The current study showed that 40 % of the lands were under permanent permits, 35 % of the lands were under annual permits and 25 % of the lands were encroachments.

3.3 Hydrological behavior in the vicinity of Agro-wells

The current study has shown that the average groundwater level fluctuates between 3.6 m – 6.9 m in the dry months (July – September) and the average groundwater level was 5.3 m. Further, about 90% of Agro-wells have at least 2.0 m water depth in the driest months (July – September) in the area. According to the findings of the study, 93% of Agro-wells in the study area were at a success level of shallow groundwater availability of at least 2 meters, even in the dry months for agricultural purposes. Only 7 % of Agro-wells were abandoned in the study area due to the limited water availability in the dry months.

After analyzing the groundwater table behavior, it has shown a similar pattern to the irrigation tank water level fluctuations and groundwater level in Agro-wells (Figure 3). It was clear that there was an interaction between irrigation tank water level fluctuations and the groundwater table fluctuations in these cascades.

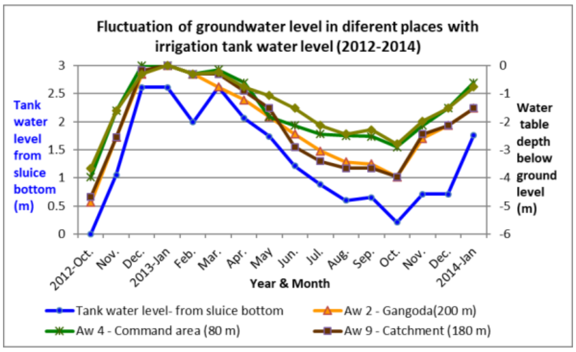

Figure 3: Fluctuations of surface water level in tanks and groundwater levels in sample Agro-wells.

Groundwater availability of the area was measured using the half recovery pumping test by comparing two tank cascades in which the Agro-well density is "high" (Periyakulama = 22 Agro-wells per km²) and "low" (Halmilla wewa = 5 Agro-wells per km²). In this study, half recovery times of both cascades were increased during the water extraction period through water pumping machines from Agro-wells, in the dry season. The half recovery times of both cascades increased from May to September without outstanding differences. (Figure 4).

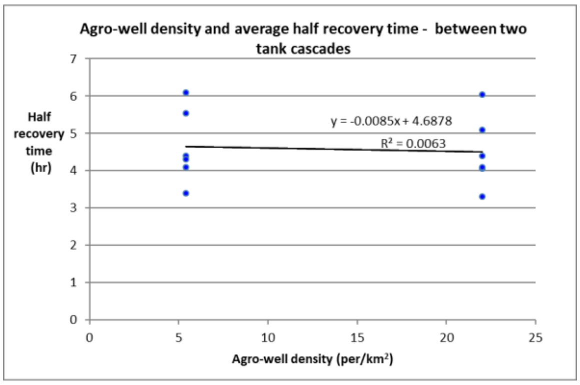

Figure 4: Comparison of the average half-recovery time

Source: Field study 2014

It was revealed that the decrease of the well-specific capacity has occurred in both cascades. High Agro-well density cascade was Y= - 0.775 X + 9.958 and, Low Agro-well density cascade was Y= - 0.650 X + 8.466, from May to September. However, the decreasing gradient was not statistically different according to the significant test (P value = 0.5362). This test revealed that the natural loss through evaporation and percolation in both cascades are prominent and have no significant impact on the groundwater availability through pumping from Agro-wells.

4. Conclusion

Availability of water in Agro-wells varies in a wide range, according to the relative location, the existence of surface water bodies, aquifer characteristics, seasonal rainfall, rate of groundwater extraction, and cascade characteristics. With the use of shallow groundwater in addition to the surface water in irrigation tank cascades in Malwathu Oya Basin, a few hydrological changes could be observed. According to the water table measurements and pumping tests, there were no significant negative impacts yet. However, the decrease in the well-specific capacity has not been significant in this sample study. However, before the 1990s, entire tank cascade areas in the dry zone of Sri Lanka depended on only surface water resources for agricultural purposes. With the intervention of Agro-wells in tank cascades, the entire hydro-ecology, as well as the management system, has been changed into a groundwater-based cropping system in the dry season, in addition to the surface water use for the paddy cultivation in the rainy season. However, these sample cascades have shown that groundwater extraction has not created a significant negative impact on regional hydrology.

References

1. Dharmesena, P.B. Half Recovery Time: An Indicator for Well Water Availability. In Proceedings of the 50th annual session of Sri Lanka Association for the Advancement of Science. Colombo: 1994.

2. Kikuchi, M. et al. Agro-well and Pump Diffusion in the Dry Zone of Sri Lanka (Research Report–66), Colombo; International Water Management Institute. 2003: 1-25.

3. Panabokke, C.R. Nature of Occurrence of the Regolith Aquifer in the Hard Rock Region of the North Central Dry Zone and its Rational Exploitation for Agro-well Development. In: Pathmarajah, S. (ed), Use of Groundwater for Agriculture in Sri Lanka - Symposium Proceedings, Peradeniya: Agricultural engineering Society of Sri Lanka. 2002: 10-22.

4. Madduma Bandara, C.M. Groundwater Resources in the Dry Zone Hard Rock Areas. Annual Sessions of the Ceylon Association for the Advancement of Science: Colombo. 1973.

5. Dharmasena, P.B., and Goodwill I.M. Use of Ground Water in Minor Tank Irrigation Schemes of Sri Lanka. In Proceedings of 17th International Congress on Irrigation and Drainage. Granada, Spain: 1999-175-194.

6. Sakthivadivel, R., Fernando, N., and Brewer, J.D., Rehabilitation Planning for Small Tanks in Cascades (Research Report 13). Colombo: International Irrigation Management Institute.1997- 3-17.

7. Dharmasena, P.B. Integrated Management of Surface and Ground Water Resources in Tank Cascade Systems. In: Pathmarajah, S. (ed), Use of Ground Water for Agriculture in Sri Lanka - Symposium Proceedings, Agricultural Engineering Society of Sri Lanka: Peradeniya, 2002. 53-65.

8. Panabokke, C.R. Nature of Occurrence of the Regolith Aquifer in the Hard Rock Region of the North Central Dry Zone and its Rational Exploitation for Agro-well Development. In: Pathmarajah, S. (ed), Use of Groundwater for Agriculture in Sri Lanka - Symposium Proceedings, Peradeniya: Agricultural engineering Society of Sri Lanka. 2002. 10-22).

9. Mapa, R.B., Somasiri, S., Dassanayake, A.R. Soils of the Dry Zone of Sri Lanka; Morphology Characterization and Classification. Peradeniya: Soil Science Society of Sri Lanka. 2010.

10. De Silva, S. Sustainable Use of the Precious Groundwater Resources in Sri Lanka through a Systematic Research Approach, in Status and Future Direction of Water Research in Sri Lanka. Colombo: IWMI. 1998.

11. Dharmasena, P.B. Resource Management Studies on Agro-well Farming in the Dry Zone of Sri Lanka – Project Terminal Report, Mahailluppallama: Field crops research and development institute. 1998.

12. Perera, M.P. Groundwater Extraction through Agro-wells and its Impact on Groundwater Availability of Tank Cascades in the Dry Season: A Case Study in the Dry Zone of Sri Lanka, International Journal of Scientific Research and Innovative Technology. United Kingdom. 2017. 4 (6): 50-62

13. Govt. of SL. Agro-well survey Report, Provincial Agricultural Ministry. Anuradhapura. 2010.

14. Perera, M.P. Development of Agro-well Lands and Its Impact on Soil Salinity in the North Central Dry Zone of Sri Lanka, International Journal of Science and Research (IJSR). 2016. 5(7): 497-501. DOI: 10.21275/v5i7.ART2016217

