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Nature of occurrence and sustainable use of groundwater resources for agriculture in the North Central, North Western and North Eastern regions of Sri Lanka

C.R. Panabokke
Water Resources Board, 2A, Gregory's Avenue, Colombo 07, Sri Lanka

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INTRODUCTION

A very rapid exploitation and utilization of the shallow groundwater resources of the North Central, North Western and North Eastern regions (Figure 1) has been taking place over the last twenty years. This rapid development has, however, taken place without an adequate understanding of the real nature and behaviour of these shallow, naturally occurring groundwater bodies or aquifers.

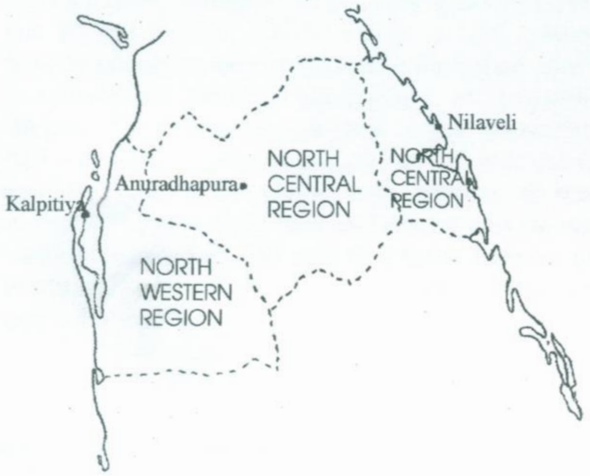


Figure 1

In the North Central region (Figure 2), this development has been taking place in the so-called "hard rock" or crystalline basement complex of rocks which are well known for their very limited quantities of shallow groundwater. It is now recognized that this shallow groundwater benefits from the presence of several small tank cascades systems that are distributed across this landscape. This has enabled the recent development of agrowell farming, especially in the Anuradhapura district where it is reported that around 15,000 agrowells are in operation; and almost all of these are situated in the lower aspects of the shallow inland valleys which receive some degree of seepage from the small village tanks that are located upstream.

In constrast, both in the North Western and North Eastern regions a similar rapid development has

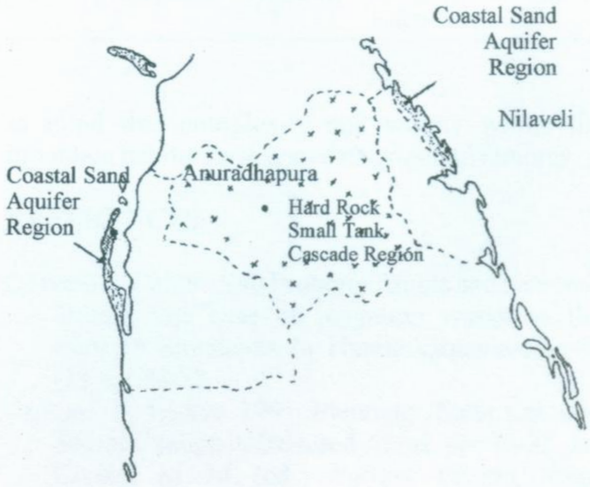


Figure 2

been taking place on the sandy regosol landscape which is underlain by the well known Gyben-Herzberg lens of fresh water floating on the denser salt water. These water bodies are now referred to as coastal sand aquifers and the area of their occurrence is shown in Figure 2.

Until recent times, majority of these lands in the coastal sand landscapes were under rainfed coconut plantations, where, despite the dry zone climate, the roots of the coconut palm were able to draw their supply of groundwater from this underlying lens through the dry season. It was around the early eighties that intensive chilli, onion, and vegetable cultivation commenced by making use of low- head lift irrigation. This was specially so in the Kalpitiya Peninsula, where, by the early nineties, alarming levels of groundwater pollution were being observed in these intensively farmed market-garden areas. The Nilaveli - Kuchchaveli coastal belt which was a reputed'tourist settlement area in the past has recently been converted into an area of highly intensive onion cultivation by the use of low head lift irrigation devices, where at least two onion crops are grown during each dry season. It is now reported that there are around 400 agro wells and a further 400 domestic wells located across an area of 1,600 ha between Nilaveli and Kumburuppidi.

Occurrence and Main Characteristics of these Shallow Aquifers

Regolith Aquifer

It is now well recognized that the groundwater resource in the hard metamorphic rock regions of the North Central dry zone is made up of the shallow 'regolith' aquifer as characterized by Herbet Ball, Rodrigo and Wright (1988), and the deeper 'fracture zone' aquifer which occurs in the underlying fracture zone at depths of more than 30 m. The nature of occurrence of this regolith aquifer, its behaviour and its distribution in the landscape, has been describe by Panabokke (2002).

This shallow regolith aquifer is mainly confined to the narrow inland valley systems of the undulating mantled plain landscape situated within agroecological region of DLI.

The thickness of this regolith is variable and is not greater than 10 m in this region. Both agrowells as well as the domestic wells exploit this shallow phreatic water table which is present within this regolith substratum up to depths of between 6 to 8 m. The water holding and transmissivity capabilities of the regolith aquifer are comparatively limited.

During the early years of agrowell development in the North Central region it was observed that most of these agrowells were distributed around the small tanks and in close proximity to the village tank settlements. The indigenous knowledge of the villagers was used in siting these early agro wells. It is now clearly recognized the small village tanks themselves are found to occur in the form of distinct cascades, and that the shallow regolith aquifer is in turn located around the valley floors of these cascades of small tanks. Field measurements carried out both in Sri Lanka and South India indicate a very good correlation between tank water levels and groundwater levels in the command area under these tanks. As a result, this shallow regolith aquifer is mainly confined to the main valleys which make up the cascade of small tanks. A schematic depiction of its occurrence within a cascade of small tanks is shown in Figure 3.

Coastal Sand Aquifer

Three main types of coastal sand aquifers have been recognized and characterized in Sri Lanka (Panabokke and Sakthivadivel 2002), of which two are relevant to this paper. These are

1. Shallow aquifers on coastal spits and bars as found in Kalpitiya, Pooneryn and Mannar Island in the North Western region.
2. Shallow aquifers on raised beaches as found in Nilaveli - Kuchchaveli, Pulmuddai and Kalkudah in the North Eastern region.

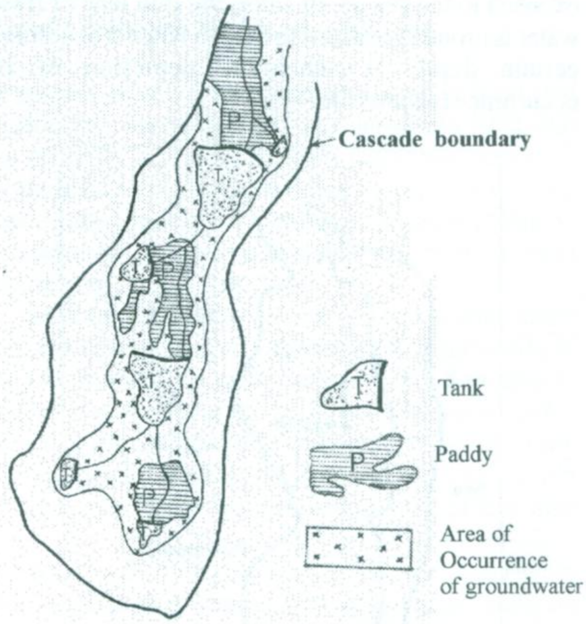


Figure 3. Schematic Representation of Groundwater area within a Cascade

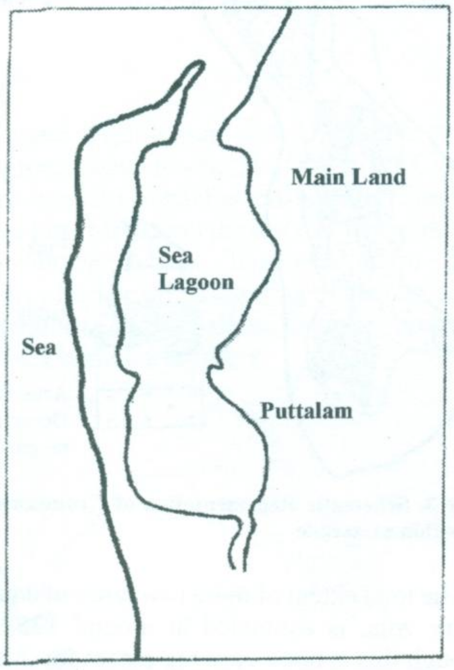
The total extent of these two types of aquifers in the dry zone is estimated at around 125,000 ha. Although this is not a very big extent for this island nation, it constitutes a limited but very precious resource of highly renewable groundwater supply that supports both intensive human settlement, flourishing tourism and most of all, a very high value intensive agriculture.

These aquifers are re-charged mainly during the 3-4 months of rain during the wet 'maha' season, when the falling rainwater infiltrates into the ground and collects in the form of fresh water lens of varying thickness which is termed the Gyben-Herzberg lens according to Sirimanne (1952).

Any over - extraction of this fresh water lens results in the coning, or entry of the underlying brackish or salt water into this lens of fresh water. This is particularly significant in the very dry regions of the North Western region where the amount of recharge of fresh water will depend on the amount of wet season rainfall experienced in any particular year.

The Kalpitiya peninsula is what geomorphologists describe as a 'spit' which is essentially a narrow shoal of unconsolidated off-shore sandy material projecting into the sea from the shore. Such a geomorphic setting is highly conducive to the build up of the typical Gyben-

Herzberg lens of fresh water floating on the underlying brackish water. This fresh water lens is re-charged only during the North East monsoon maha rainfall. Since this particular landform is exposed to the sea on all sides, the thin lens of fresh water is prone to leak out to the sea when it acquires a certain depth. A schematic depiction of its occurrence is shown in Figure 4.



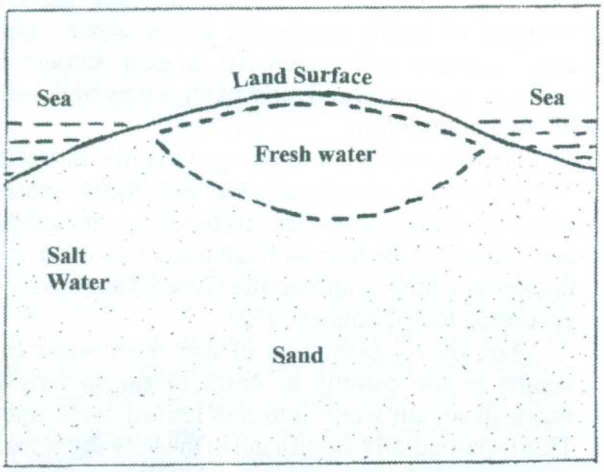


Fig. 4. Schematic section across Kalpitiya aquifer

The 'raised beach' type of landform is found in the Nilaveli - Kuchchaveli coastline .and it lies well above the present sea level. These raised beaches are 3.0 to 3.5 m above m.s.l. and generally more than 100 m in width. Here too, the falling rainwater infiltrates into the ground and collects in the form of a fresh water lens of varying thickness dependent on the dimensions of the beach. A schematic depiction of its occurrence is shown in Figure 5.

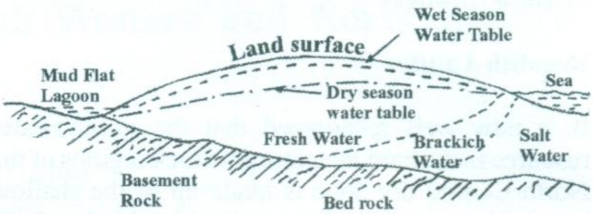


Fig. 5. Schematic cross section of Nlaveli coastal auuifer

As in the case of the previous type, any over extraction of this fresh water lens results in the 'coning' or entry of the underlying brackish or salt water into the lens of fresh water.

Since this aquifer is bounded by the sea only on its eastern flank, and by the lagoon and mud flats on its western flank, it can hold up the groundwater for a longer period than in the case of the Kalpitiya aquifer which is bounded by the sea on both sides. It also recess a higher rainfall during the North East monsoon season which enables it to store more water-within the surface lens.

Recent Trends in Utilization of Groundwater Resources and Potential Hazards of Over-Exploitation

Regolith Aquifer

The use of shallow groundwater from the regoligh aquifer zone in the hard metamorphic rock areas of the North Central region has progressed very rapidly during the last fifteen years. The former Agricultural Development Authority (ADA) had been promoting the agro-well development programme in the Anuradhapura district from mid 1980's, in order to help small farmer cultivate high value crops under lift irrigation during the dry 'yala' season. It is estimated that in the Anuradhapura district alone it had assisted nearly 15,000 farmers to construct open dug wells (agro wells) usually 5 to 10 m depth and 5-7 m diameter in order to abstract limited quantities of groundwater for irrigating small plots 0.5 to 1.0 acre size for the cultivation of chilli, onion and other vegetable crops.

Because of the shallow nature of these regolith aquifers as well as their low specific yield, excessive abstraction could easily lead to a rapid lowering of the existing groundwater levels down to the bedrock. A high density of agrowells could also lead to a situation where an over extraction of the limited amount of groundwater takes place, which in turn leads to an abandonment of other agrowells in the vicinity as had happened at Paluwa in the Galgamuwa area in the early nineties. It is suggested that over extraction of the groundwater could also lower the groundwater level to such an extent so as to adversely affect the natural vegetation in a very dry year, which in turn would lead to an irreversible environmental damage.

Overall, it could be concluded that the selective use of this regolith aquifer will continue to remain a good strategy as long as the rate of extraction is less than the average annual recharge of the regolith aquifer.

Coastal Sand Aquifer

Traditionally, up to around the nineteen sixties both types of these coastal aquifers were very sparsely utilized. Water from these shallow aquifers was lifted manually and mainly used for domestic purposes by the fishing villages. In the early part of last century several rainfed coconut plantations were successfully established in the coastal aquifers of the Puttalam district and also along the Eastern sea board around Nilaveli in the Trincomalee district. Chewing tobacco was also grown by small farmers in the Kalpitiya peninsular using simple lift irrigation devices, and these co-existed with the coconut plantations.

Intensification of land use in these coastal sand areas began around the early seventies with farmers using small diesel pumps to lift water for irrigating chilllies and onions which was becoming quite profitable. Small and medium scale tourist resorts also began to develop especially around Nilaveli in the North Eastern region which draw their water supplies from these aquifers.

One of the best examples of a rapid change both in the nature and intensity of land usage comes from the Kalpitiya peninsula. With the introduction of highly profitable cash crops such as chilli, onion, potato and vegetables more dug wells began to get constructed, and mechanical pumps and year round spray irrigation used to supply crop water requirements. The rate of groundwater extraction in some parts of the peninsula has now exceeded the recharge rate. Results of monitoring of water quality now reveal a high build up of nitrate concentration in excess of the stipulated WHO standards, often exceeding 22 mg/1 for part of the year.

Monitoring of the agrowells in the Nilaveli aquifer indicate that despite the high intensity of onion cultivation there is no build up of soluble salts in the groundwater; and that both nitrate and chloride values in the irrgation water show a sharp rise by the end of the dry season, but decline to a low level after the November-December rains. It is therefore reasoned that in this environment the amount of rainfall received during the 'maha' season is sufficient to leach out and dilute the solutes that have built up in the soil during the dry 'yala' season and also as a result of recycling of irrigation water by intensive irrigation.

Results of Recent Monitoring Studies

In respect of the reuolith aquifer, results from two exploratory studies, one by Kendaragama 1993, and the other by Ariyabandu 1996 have been reported; while results from a more detailed systematic study carried at on ninety four agrowells located within 35 cascades in the Anuradhapura district have been reported by Perera *et al.* 2001.

Results of the above exploratory studies show that the quality of groundwater in the agrowells of the Anuradhapura and parts of the Kurunegala district is suitable for the irrigation of the commonly grown crops; and also that there was no risk from any sodium hazard developing because the SAR values of the tested water samples had a value of less than ten.

Results from the Perera's systematic study show that 50 percent of the 94 agrowells studies have an EC value of between 500 to 1,000 umhos/cm, and that 30 percent of the agrowells have and EC value of between 1000 to 2000 umhos/cm. Values of EC higher than 2000 umhos/cm were reported from only 5 percent of the agrowells.

The depth of water columns in the agrowells showed a gradual increase from September to January and a steady decline from April to- August. At the end of the dry season, wells in the Kebithigollewa, Kahatagasdigiliya and Horowapathana D.S. Divisions had a depth of water columns of more than 1.5 m which indicated their better groundwater status endowment; while wells in the Vilachchiya and Palagala D.S. Divisions had a depth of water column less than 1.0 m which indicated their poorer status of groundwater endowment.

Several studies have been reported in respect of the coastal sand aquifers both in Kalpitiya as well as in Nilaweli - Kuchchaweli. The Kalpitiya coastal sand aquifer has been studied over the period 1985 to 1991 by the Department of Agriculture (DOA) and the British Geological Survey (BGS) under an ODA assisted programme. The Nilaweli coastal sand aquifer has been studied by the Water Resources Board (WRB) in collaboration with GTZ from 1999 to present.

Results of monitoring of agrowells in Kalpitiya show that the EC values of the groundwater varied from 400 to 1,500 umhos/cm over most of the peninsula. Lawrence and Kuruppuarachchi (1989) have reported that while the quality of groundwater over large areas of the peninsula is good, it is observed that within the cultivated areas, the concentrations of nitrate, potassium and chloride are exceptionally high. Kuruppuarachchi and Fernando (1999) also report that the build up of nitrate and chloride is quite dramatic and has been estimated at 1-2 mg N $^{-1}$ and 5 mg Cl 1 $^{-1}$ per annum respectively.

Results of monitoring of agrowells in the Nilaweli - Kuchchaweli area as reported by Panabokke *et al.*, (2002) show a rise in EC values following the early 'Maha' rains followed by a period of stability in February - March, and then a sharp decline after the April rains. The concentrations of nitrate and chloride also show a rise in initial values in September followed by a decline in values after January - February. In summary, it could be concluded that at present there is no evidence of a build up in the concentration of solutes in these agrowell waters. It could be reasoned that the quantity of Maha' season rains received is sufficient to leach out solutes that have built up during the dry season. It would, therefore, be concluded that this Nilaweli aquifer is of a more benign and robust nature than the Kalpitiya aquifer.

Approaches towards a Sustainable Exploitation of the two Types of Aquifers

Regolith Aquifer

As could be seen from the preceeding sections of this paper, there is an upper limit beyond which the exploitation of the regolith aquifer would result in an irreversible degradation of this precious groundwater resource. In a study conducted on 50 cascades within the Anuradhapura district, Senaratne (1996) has shown that the optimum number of agrowells that would be safely accommodated within these 50 cascades is not more than 3,600 ; and that already within 5 of these 50 cascades, the number of agrowells has already exceeded the upper limit.

Studies conducted by De Silva (1997) have also shown that the key aquifer parameters such as hydraulic conductivity and specific yield are very poor for most of these regolith aquifers and, as a result the rate of well recoveries are also very poor. Therefore, the pumping schedule and abstraction rates should match the seasonal recharge rates within an agrowell in order to avoid drying up of the well during the cropping season. De Silva (2002) has also observed and reported from select studies conducted by her that the annual average recharge was only 10 to 15 percent of the annual rainfall, and that a major proportion of this recharge takes place during the rainy season from late October to late December. However, it has also been observed that in some areas where these studies were conducted, this amount of recharge was not sufficient to fully replenish the shallow regolith aquifer. Based on select aquifer parameters and their recharge capacity, a set of nomographs has been developed by De Silva (1997) and these could be effectively used to regulate utilization of this limited groundwater supply on a sustainable basis, Based on the foregoing considerations, it is now possible to limit the future development of agrowells according to the carrying capacity of the aquifer by use of the above nomographs. Dharmasena (2000) has very correctly shown that since the regolith aquifers have very limited resources of groundwater, at least 25 percent of the potential groundwater storage in an aquifer should be reserved in order to meet environmental requirements. His recommendation that an agrowell should have a minimum water depth of 1.5 m at the end of the dry season has been supported and confirmed by the monitoring studies carried out over a 24 month period by the Water Resources Board (WRB) in the Anuradhapura district.

Coastal Sand Aquifer

As previously shown, there is a clear difference in behaviour between the Kalpitiya coastal sand aquifer and the Nilaweli coastal sand aquifer. Being located on a 'spit' with the sea and lagoon on both sides, the Kalpitiya aquifer is more fragile and also receives a lower 'Maha' season rainfall for recharge. The Nilaweli aquifer in contrast, being located on a raised beach with the sea only on its eastern flank and also experiencing a higher 'Maha' season rainfall, is more robust and lends itself to easier management. This is borne out by the nature of the monitoring studies reported in respect of the two aquifers.

According to Lawrence *et al.* (1986) the groundwater system in the Kalpitiya aquifer can be visualized as a series of cells as shown in Fig. 6 where " within each cell groundwater is drawn to the irrigation well and spread over the cropped area where most of the applied water returns to the water

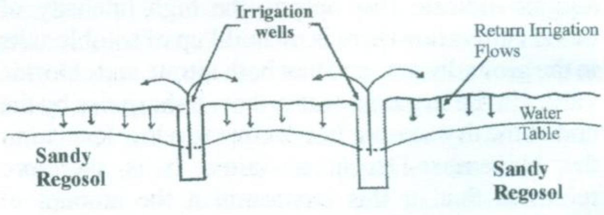


Fig. 6. Groundwater flow dominated by abstraction from Irrigation wells

table. The return irrigation flows, on reaching the water table, are unlikely to migrate beyond the cropped area". This statement aptly sums up the cyclic path of the limited irrigation water and its return to the underlying aquifer directly below the cultivated surface area.

Bearing this in mind, one should not be too complacent regarding the sustainability of these aquifers under the present irrigation and water management practices. A systematic and well conceived monitoring programme on both the quality and quantity of the aquifer on a sequential seasonal basis is of prime importance if the sustainable use of these fragile aquifers is to be ensured. Although at present it is observed that the groundwater in wells located outside the intensively cultivated areas is generally of good quality and does not appear to be significantly affected by diffusion of pollution solutes, adequate safeguards should be set in place to ensure their sustainability.

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