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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Water use in agriculture

The influence of irrigation on groundwater

A completed WRC project has provided an initial assessment of the impact of irrigation on groundwater quality at Vaalharts Irrigation Scheme.

Drainage and salinity issues at Vaalharts

The Vaalharts irrigation scheme, developed in the 1930s, receives its water from the Vaal River via a diversion weir situated near the town of Warrenton. Currently the scheme includes 1 200 plots that vary in size from 25 to 75 ha, covering a total area of 35 302 ha (31 732 ha in the Northern Cape and 3 570 ha in the North-West Province).

To provide relief from the waterlogging and salinisation problems being experienced in the area, the installation of a main sub-surface drainage system began in 1972, with feeder canals being lined with concrete. However, in 2000, it was discovered that approximately 50% of the plots did not have proper discharge points for drainage water. Currently almost 60% of the plots have internal drainage, with many applications for further installations still receiving attention.

Waterlogging and salinisation remain problems, as the water table has risen from 24 m below ground level (mbgl) at the inception of the scheme to a current average of 1.6 mbgl. An investigation in 2004 indicated that the macro salt input and output of the scheme is not in balance resulting in a lower-than-expected salt input into Spitskop dam downstream of Vaalharts, indicative of salt retention within the scheme. The associated deterioration in the quality of groundwater has been indicated by the analysis of groundwater samples and on-site EC measurements.

Investigating the effect of irrigation on groundwater

In order to gain a better understanding of the influence of irrigation on the groundwater situation at Vaalharts, it was deemed necessary to investigate and establish:

- How different irrigation methods, on different soil types, with and without drainage, influence the water and salt mass balance and quality of groundwater in the upper zone (0-3 m) of the soil;
- The flow paths of groundwater in the upper saturated zone and of groundwater returning to the Harts River;
- The extent to which the long-term salt balance produces an accumulation of salts in the deeper aquifers; and
- The physical properties of the upper zone as a step towards the development of a conceptual model of the groundwater flow.

The approach consisted of:

- Reviewing literature and collecting background information on the existing scheme and previous studies conducted in the area;
- Installing a network of approximately 240 piezometers to allow periodic monitoring and analysis of groundwater levels and electrical conductivity (EC) profiles over one year in order to cover all seasons including the planting, harvesting, rainy and dry periods;
- Monitoring drains at selected sites;
- Measuring the hydraulic conductivity of soils and testing of aquifer parameters with a view to constructing conceptual models;
- Conceptual modelling to simulate drain flow;
- Calculating water and salt balances; and
- Evaluating options to ensure the sustainability of the irrigation scheme.

Observations and measurements

Water level measurements

Piezometer water level measurements allowed the effect of precipitation, drainage and irrigation on groundwater levels to be established. These levels were also used to create groundwater contour maps and to determine the direction of groundwater flow. The average groundwater level of the piezometers was 1.63 mbgl and the contour maps indicated that groundwater drains towards the Harts River.

EC measurements

Piezometer EC profiling was carried out by determining EC values of groundwater in all piezometers at depth intervals of 200 mm from the upper water level to the bottom of the hole. The EC readings for each piezometer were all within the same range, indicating that there is no stratification or layering of groundwater salinity within the top 3.0m of the soil in the area. The average measured EC of the groundwater was 191 mS/m, which was considerably higher than the average EC of irrigation water (66 mS/m), indicating a macro leaching fraction as high as 30%.

Hydraulic conductivity measurements

A total of 26 piezometers, representative of the area and the different soils that occur, were selected for determining values of saturated hydraulic conductivity, which were found to range between 0.013 and 5.4 m/d, depending largely on the soil clay content which ranged between 6 and 40%.

EC monitoring in drains

EC values of the drainage water at the drain outlets tended to be 11 - 20% higher than that of the groundwater in the vicinity. This difference is indicative of a salt build-up and non-effective drainage. Wherever good drainage existed and no over-irrigation occurred, the EC values of the drainage water tended to be lower, i.e. closer to those of the groundwater.

Salt and water balance

The results of consecutive studies reveal that there has been a steady build-up of salt in groundwater at Vaalharts, which is in line with a study done in 1996 showing that almost 100 000 t of salt imported via the irrigation water is not accounted for in the water leaving the scheme. A study done in 1976 had measured a groundwater TDS average of 1 005 mg/ℓ.

A later study, concluded in 2004, indicated that the groundwater TDS was1 350 mg/ℓ, representing an average annual increase of approximately 13 mg/ℓ. Piezometer measurements in the current study found the average groundwater EC to be 191 mS/m which represents a TDS of 1 476 mg/ℓ. This indicates an increase of 96 mg/ℓ in the most recent 5 years, which translates to an average increase of 19 mg/ℓ/a in the groundwater of the upper 3 m layer. Calculations suggest that, of the 4.65 t/ha/a salt input through irrigation, 0.8 t/ha/a is retained.

The possibility was raised in 1996 that the retained salts accumulate in the groundwater sources below the irrigated area by leaching through the upper soils, and that these sources act as a salt sink due to the presence of a perched water table. It was speculated that at some stage the capacity of the sink would be exhausted, with severe consequences.

The 2004 study, however indicated that there is no perched water table, confirmed by the finding in the current piezometer study that there is no stratification of groundwater salinity. The net storage of the aquifer system, which is assumed to remain stable, would in fact be consistent with a steady annual increase in the groundwater TDS of the order of 14 mg/ℓ per annum.

A subsurface flow depth of 8 m was calculated, at which depth the EC of the groundwater remained high during the entire monitoring period, with values in the range 660 - 1000 mS/m being measured. The clay content of 28% provides one emphatic reason for the salt build-up under the conditions that prevail.

Implications for irrigation

In order to flush salt that is generated in the upper layer of soil through accumulation of residual salt from both the irrigation water and the fertilisation process, leaching must take place. The application of a well maintained and functional drainage system is essential. Salinity can also be reduced by scheduling irrigation correctly and preventing overirrigation. This would result in the reduction of the drainage volume and the need for additional drains.

The average EC of the groundwater (currently 191 mS/m) is still lower than most plants can tolerate, but nevertheless much higher than that (66 mS/m) of the irrigation water. The tolerance levels for wheat, maize and lucerne are 170, 200 and 600 mS/m, respectively, which emphasises the existence of a real salinity threat unless countered through sound irrigation and leaching practice. The leaching requirement to maintain the salt balance was determined as 611.5 mm/a, which compares well with the modelled leaching value of 583.7 mm/a. The measured drainage averaged only 284 mm/a, however, which suggests that drainage is currently not effective.

Recommendations

Efficient irrigation practice in combination with effective drainage is the only way to prevent salinisation of lands. This includes the minimisation of leakage to groundwater from overnight dams, feeder canals, community furrows and open drains which need to be kept clean and their concrete linings free of cracks.

A further move from surface (flood) irrigation to more efficient irrigation systems such as centre pivots, as well the wider adoption of sound irrigation scheduling practice is to be strongly recommended. This will allow more control over water applications and prevent excessive amounts of water leaching to groundwater without being intercepted by drains.

Attention should be given to the spacing of internal subsurface drains and, where inadequate, the distance between drains should be reduced.

Finally, careful maintenance of irrigation equipment (including pumps, pipes, nozzles, standpipes, hydrants, valves, etc.) as well as of the internal subsurface drains (through regular cleaning and replacement when necessary) is of the utmost importance.

Further reading:
To obtain the report, ***The influence of irrigation on groundwater at the Vaalharts irrigation scheme – preliminary assessment*** (**WRC Report No. KV 254/10**), contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.