WATER RESEARCH COMMISSION

October 2013
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

Irrigated agriculture

Managing salinity associated with irrigation

The WRC has funded a solicited research project on managing salinity associated with irrigation in selected areas of South Africa.

Background

Salinity associated with irrigation has in the past, and continues to be arguably the most important factor threatening agricultural production under irrigation. Unfortunately the problem extends beyond the confines of irrigated fields, degrading water resources and resulting in extensive areas of land becoming waterlogged and saline. Poor planning and ineffective water and salt management practices by farmers and managers of irrigation schemes therefore strongly affect the sustainability of irrigation.

Researchers are in agreement about the fact that sustainable irrigation is technically possible with the proper design and operation of irrigation and drainage systems, together with the implementation of suitable crop and soil management practices, provided that acceptable political and social structures are in place. The general opinion is that irrigated agriculture will not only survive, but will indeed thrive under realistic circumstances and appropriate management practices.

Increasing pollution problem

The estimated fraction of salt-affected irrigated land in South Africa is only 9%, which is much lower compared to countries such as Argentina (34%), Egypt (33%), Iran (30%), Pakistan (26%) and the US (23%). Up to 12% of the total irrigated area in South Africa is severely waterlogged or salt-affected, and 5% to 20% moderately affected.

Salinity problems have been reported occasionally in the Breede, Berg, Great Fish and Sundays Rivers. Ten irrigation schemes have shown increases in mean river water salinity from upstream to downstream over the length of the scheme, viz. Breede River, Great Fish River, Groot River, Hluhluwe River, Lower Vaal River, Modder River, Pongola River, Riet River, Tarka River and Vaalharts.

Despite the fact that salt-related problems are not presently a significant factor threatening production under irrigation in South Africa, increasing evidence of deterioration of physical resources suggests that the problem cannot be ignored.

For this reason this WRC project was solicited. A general aim of the project was to develop best practices and guidelines for managing the salt load associated with irrigation at farm and scheme level.

Selected irrigation schemes

The study was conducted at the Orange-Riet and Vaalharts Irrigation Schemes in semi-arid South Africa. The two irrigation schemes were selected for the following reasons:

- Irrigation has been practised for more than 70 years on both schemes, which is important for salt to reach equilibrium at this level;
- The two schemes have a range of crops, soils and irrigation methods, with and without artificial drainage to study water and salt balances;
- Water of different quality is used for irrigation since water is transferred between some sources in this region;
- Both schemes are managed by well-organised water user associations which have reliable data essential for the project;
- On each of the schemes there is a large knowledge base concerning water and salt-related problems and their management;
- Logistically, the location of the two schemes suited the project team for detailed measurements.

- Several farmers at both schemes had a sincere interest in the project and their collaboration proved to be valuable
- Water and salt-related problems were experienced occasionally at the two schemes

Research approach

In addressing the stipulated objectives of this solicited project, literature was studied to formulate eventual best management strategies for salinity associated with irrigation at farm and scheme level. Next, sites and measuring points were identified at the Orange-Riet and Vaalharts Irrigation Schemes where data were collected over four cropping seasons to study the mechanism of water and salt movement under a range of crops, soils and irrigation methods, with and without artificial drainage.

These measurements yielded good quality data for the calculation of short-term water and salt balances covering a large range of situations. It was thus decided to use a local model (i.e. SWAMP) known to the project team to test scenarios of salinity management in the long term.

In a successive series of simulations using experimental data, crop selection under irrigation, response of soils to irrigation management, effect of irrigation on crop production, and irrigation scheduling methods were assessed by using SWAMP-generated simulations. Based on the outcome of these simulations, best management practices are suggested.

Main research findings

Improvement and utilisation of the SWAMP model

The success of this project depended on obtaining an appropriate method to acquire water and salt balances at the two irrigation schemes. The fact that most of the measuring points at Orange-Riet and Vaalharts had shallow water tables was problematic. To overcome this problem, the SWAMP model was introduced, because it is known for its ability to estimate the soil water balance components under dryland and irrigation conditions, including water tables. However, the model has a major weakness as it has no salt balance subroutine. Such a subroutine was consequently developed through this project.

Assessment of crop selection under irrigation

The focus of this study was on field crops, although perennial crops such as lucerne, grape, pecan nut and citrus are cultivated in the irrigation schemes. The most popular practice at Orange-Riet and Vaalharts is a continuous wheat-maize sequence. These farmers often replace wheat with either barley or peas as a control measure against pest infestations. If peas are not an option, a winter fallow is introduced. A dual cropping practice, i.e. where the irrigated land is divided into halves, was evaluated in situ over four growing seasons at Vaalharts.

A 20-year-long predictive modelling study was undertaken with SWAMP to investigate the effect of salinity on crop yields. Four popular crop sequences were used. The results showed that the mean salinity of the sandy loam soil used in the study never rose above 350 mS m^{-1} in any of the crop sequences, posing a risk only to peas. The simulated yields confirmed that peas were affected by the prevailing salinity conditions induced by the irrigation practice.

The reason why soil salinity did not increase to detrimental levels for the other crops can be explained by the leaching of salts by excess rain during infrequent heavy rainfall events. Thus, it seems that climate plays a significant role in protecting the crops against the harmful effect of salt accumulation in soils.

Assessment of soil response to irrigation management

Despite the long history of irrigation, it can be concluded that the salinity of the soils is generally low in both schemes. The mechanisms associated with how these soils maintained a low salinity was revealed through the detailed in situ assessment over four cropping seasons. The cases studies selected were a sandy and a clayey soil from the Lower Riet River area. The water and salt balances showed that between 72% and 89% of the total salt additions in the sandy soil leached from the profile, mainly due to excess rain during the fallow periods.

Drainage, on the other hand, only accounted for 9% of the total salt removal in the clayey soil. Despite the low salt removal by drainage the electrical conductivity (EC) of the soil extract remained consistently low over the four seasons, which led to the hypothesis that precipitation may have removed the solutes from the water phase. However, this hypothesis was never tested and needs clarification in future research.

The extent to which soils affect hydro-salinity processes and crop yields under long-term irrigation was also addressed. The results revealed that the soils responded uniquely. Huge differences in water and salt accumulation were found which affected the crop yields.

Assessment of irrigation water salinity on crop production

Water quality sample testing indicated that the EC and sodium adsorption ratio (SAR) values for water from the Orange River were 21 mS m^{-1} and 0.38 respectively, compared to the corresponding simulated long-term means of 19 mS m-1 and 0.38. In turn, EC and SAR values for the Vaal River were 68 mS m^{-1} and SAR 1.37 respectively, compared to the corresponding simulated long-term mean of 52 mS m^{-1} and 1.17. From these results it can be included that the water quality of both rivers is still suitable for irrigation.

Assessment of irrigation scheduling methods

Four irrigation strategies for managing plant available water were assessed in a long-term predictive modelling study with the SWAMP Model:

- In Strategy A, irrigations were calculated to meet the potential evapotranspiration, taking into account the contribution of water tables and rain;
- Strategy B is similar to A, except that the contribution of water tables was ignored in the estimation of the irrigation schedule;
- Strategy C made use of the bonus that actual evapotranspiration is known, but ignores the osmotic effect on the plant available water;
- Strategy D caters for build-up of salts in the profile until a point before the osmotic effect impacts negatively on the balance of water supply and demand functioning of the system.

Investigations showed that using Strategies A, C and D results in considerable irrigation water savings, while salt additions through irrigation are reduced. Due to a lack of irrigation-induced salt leaching, short-term (3 years) salt accumulation in the root zone can be expected, but leaching by rain occurs frequently. These strategies, when used by some farmers will be sustainable, but when all the irrigators on the schemes convert to either of these strategies a real-time salt monitoring system should be put in place.

Best management practices and guidelines

The guidelines that were developed for field-scale application take into account the following variables: soil type, irrigation water salinity, rainfall, water table uptake, leaching fraction, root-zone salinity of the root-zone, reuse of drainage water and selection of crops.

The study concludes that continuation with the status quo with a sufficient supply of water might be sustainable in the long term. Short-term restrictions in water supply can be accommodated, and with the use of present knowledge, the impact may be minimised. A permanent reduction in water supply will force irrigators and administrators to introduce more sophisticated management practices.

Further reading:
To order the report, ***Managing salinity associated with irrigation at Orange-Riet and Vaalharts irrigation schemes*** (**Report No. 1647/1/12**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za, or Visit: www.wrc.org.zato download a free copy.