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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.

POLICY BRIEF

Effectively monitoring waterlogging and salt accumulation on irrigation schemes

A recently completed Water Research Commission (WRC) project has tested new methodologies and developed knowledge towards the wide-scale monitoring of waterlogging and salt accumulation on selected irrigation schemes. The project has successfully tested the use of remote sensing (i.e. satellite) technology to monitor waterlogging and salt accumulation, and determined that the irrigated area affected by these phenomena is much less than previously thought.

Background

The high costs of measuring waterlogging and salt-affected soils on South African irrigation schemes, as well as inconsistencies in data collection and reporting methods, have resulted in incomplete and often contradictory information on the extent and distribution of salt-affected and waterlogged soils.

It is estimated that waterlogging, salinity and sodicity currently affect between 8 to 18% of the area under irrigation in South Africa.

Typical salt-affected soil showing salt precipitation.

Since the late 1980s no national effort has been made to quantify the extent of waterlogging and salt accumulation across irrigation schemes in South Africa. Indications are that soil and water quality are declining, and these problems are actually escalating. In order to identify soils for drainage and reclamation, the extent of waterlogging and accumulation has to be determined.

National monitoring of waterlogging and salt accumulation is a high priority, but currently no proven methodology is available to undertake this task. Therefore a methodological approach at appropriate scales had to be tested before application at national level.

This WRC project therefore set out to develop and test a methodological approach to identify, classify and monitor the extent and degree of waterlogging and salt accumulation at farm, irrigation scheme and national level.

Methodology and main results

The only viable option for monitoring waterlogging and salt accumulation over large areas (i.e. irrigation scheme level) is to use existing soil maps (where available), terrain data and satellite imagery to identify areas where these processes are likely to occur. By combining various sources of data and priori knowledge, large areas can be eliminated from further consideration and specific areas can be highlighted as being potentially affected.

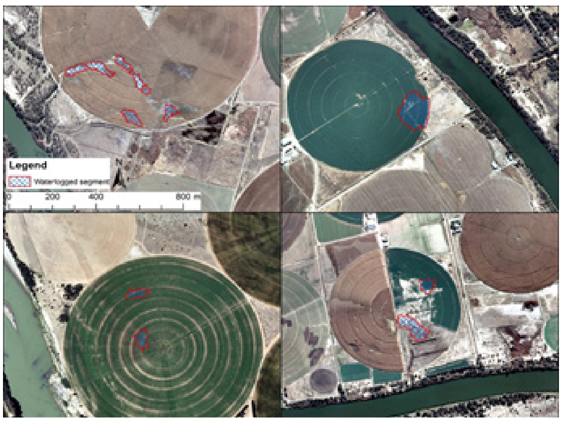
An experimental approach was taken in developing a suitable methodology for quantifying and monitoring waterlogging and salt accumulation. Various sources of data and techniques were applied and compared to empirical (reference) data to determine their potential for monitoring waterlogging and salt accumulation.

Ultimately, three approaches to mapping waterlogged and salt-affected areas were identified as having potential for future use application. The first is a **modelling approach** whereby hydrological, terrain and soil data is used to determine where waterlogging or salt accumulation is likely to occur. Another approach is to differentiate affected and unaffected soils by making use of remotely-sensed imagery (hyperspectral or multispectral) to analyse their spectral properties. This **direct remote sensing method** is consequently applied to exposed (bare) soil.

The third approach, referred to as the **indirect remote sensing approach**, examines vegetation response (e.g. loss of biomass) to saline or waterlogged conditions. The latter approach mainly makes use of vegetation indices (VIs) derived from multispectral imagery. All three of the above approaches were consequently evaluated in this research.

Field verifications were also undertaken of the various satellite images at selected irrigation schemes across the country. Historical soil maps and reports were also used to identify problematic areas and to compare the change in salt-affected and waterlogged soils over time.

For the direct remote sensing approach, a WorldView-2 (WV2) satellite image was used to investigate if there are any spectral features of affected soils that can be used in their discrimination. The WV2 image was ideal for this purpose as it had the highest possible spatial (0.5 m) and spectral (8 bands) resolution.



Satellite image showing waterlogging.

Experiments with the direct remote sensing approach showed that there were a number of statistically significant relationships between image features and salt accumulation. However, the use of the WV2 imagery to identify salt-affected soils was found to be unreliable as all of the methods evaluated grossly overestimated salt accumulation.

This was attributed to the inconsistencies in the visual appearance of salt-affected soils as in many cases there is no visible evidence of salt accumulation.

Another factor that complicates the detection of salt accumulation when bare soils are observed using remote sensing is the disturbance caused by soil preparations (e.g. ploughing) as this can alter the soil surface and reflectance. But the main limitation of the direct approach is that a relatively small proportion of fields in irrigation schemes are bare at any given time during the year. The implication is that multiple analyses will be required to map an entire irrigation scheme.

The indirect remote sensing approach was evaluated in the Vaalharts and Breede River study areas. The WV2 image of a lucerne field at Vaalharts was used for evaluating vegetation response to saline conditions. Several experiments were also carried out to investigate the impact of reduced spatial and spectral resolution of satellite imagery.

Regression analyses were carried out to investigate the relationships between the image features and electrical conductivity (EC) values of 30 soil samples collected in the field. The results showed that there are significant and strong continuous relationships between EC and several of the features considered. Generally, the strength of these relationships diminished as the spatial resolution was reduced.

Overall, the regression analysis and classification and regression tree (CART) results were very promising as they showed that Vis generated at 6 m resolution can potentially be used. The results also suggested that high resolution texture features can potentially be used together with Vis for the indirect monitoring of salt-affected soils.

Furthermore, the relatively high spectral resolution of the WV2 imagery is not critical as the VIs performed relatively well compared to the performance of the individual bands.

It was concluded that, due to its relatively high cost, the operational use of WV2 imagery for regular monitoring of large areas is not viable. The results show that slightly lower spatial and spectral resolution imagery might produce comparable results.

The final set of experiments investigated the efficacy of elevation data and its derivatives for modelling salt accumulation at irrigation scheme level. Most of the methods evaluated either underestimated or overestimated salt accumulation or achieved low accuracies.

While not all of the experiments were successful, they provided a better understanding of the complexities involved in monitoring salt accumulation and waterlogging in irrigation schemes.

Conclusions

In this project various data sources and methodologies for the identification of areas prone to salt accumulation and waterlogging were investigated. This includes land cover mapping, bare soil analysis (direct approach), multi-temporal crop condition monitoring (i.e. indirect approach), terrain analysis, within-field anomaly detection, and decision tree analysis.

The occurrence of salt accumulation and waterlogging in generally small patches in South African irrigation schemes poses unique challenges and will require a robust modelling strategy.

It has been concluded that no model based on remotely-sensed data will ever replace in-field monitoring. The purpose of this study was to develop a method to detect potential areas of salt accumulation or waterlogging so that in-field monitoring can be performed.

Various factors have to be considered when selecting a specific source of satellite imagery for a classification project. The spatial, spectral and temporal solutions are important factors, as is cost.

Despite the effort of the science community, there is currently no robust model for accurately and consistently extracting soil water content or soil salinity from synthetic aperture radar imagery. This science is very much still in an experimental phase, and most authors agree that great strides still need to be made before such an application can be operational.

The direct and indirect remote sensing approaches show the most promise as they can be applied to high resolution, multispectral satellite imagery. Statistical methods such as regression, partial least squares regression and multi-regression have been shown to be successful in a number of studies and should be investigated further.

Due to the costs involved in soil sampling and analysis, the only viable option for monitoring waterlogging and salt accumulation over large areas (i.e. irrigation scheme level) is to use existing soil maps (where available), terrain data and satellite imagery to identify areas where these processes are likely (or unlikely) to occur.

Of the various methods experimented with the within-field anomaly detection method showed the most promise. Using this method the extent of affected irrigation areas was quantified for South Africa. It was found that on average, 3.3% of the area on nine irrigation schemes considered was affected by waterlogging and salt accumulation. This estimate was adjusted to 6.27% by adding abandoned fields. This translates to 94 050 ha of land under irrigation.

Recommendations

South Africa must adopt standardised monitoring, assessments, modelling and mapping methodologies/ procedures to improve the quantification and qualification of salt-affected and waterlogged soils on a scheme and national scale.

Viable permanent irrigated agriculture requires periodic information on salts and water tables. A network of representative monitoring point (benchmark soil sites) should be established on irrigation schemes in conjunction with remote sensing.

Assessment and monitoring of salt-affected soils with remote sensing should include associated salts/metals, e.g. magnesium, boron, manganese, chloride etc.

Areas on existing irrigation schemes which have been abandoned due to waterlogging and salt-affected soils should be identified using historical aerial photography and satellite images.

Further reading:
To order the report, *Methodology for monitoring waterlogging and salt accumulation on selected irrigation schemes in South Africa* (**Report No. TT 648/15**), contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.