Management of human-induced salinization in the Berg River catchment (South Africa)

N. Jovanovic[1], R.D.H. Bugan[1], A. Maherry[1], W.P. De Clercq[2], M.V. Fey[2], J. Helmschrot[3] and W.-A. Flügel[3]

[1] CSIR, Natural Resources and Environment, South Africa
[2] University of Stellenbosch, Department of Soil Science, South Africa
[3] Department of Geoinformatics, Hydrology and Modelling, Friedrich Schiller University Jena, Germany

Keywords: Berg River, dryland salinity, hydrological modelling, land use, semi-arid climate

Introduction

The Berg River (*Figure 1*) is a major source of water to the City of Cape Town and West Coast District Municipality, irrigated agriculture and the industries of Saldanha (South Africa). The South African Department of Waters Affairs and Forestry has found increasing trends in salinity in the Berg River since the mid 1970's. Degrading water quality limits the usability of the water in an already water stressed, semi-arid area. Natural dryland salinity (predominantly NaCl salts trapped in Proterozoic Malmesbury shale sediments) has been identified as the source of some of the salts affecting its water quality.

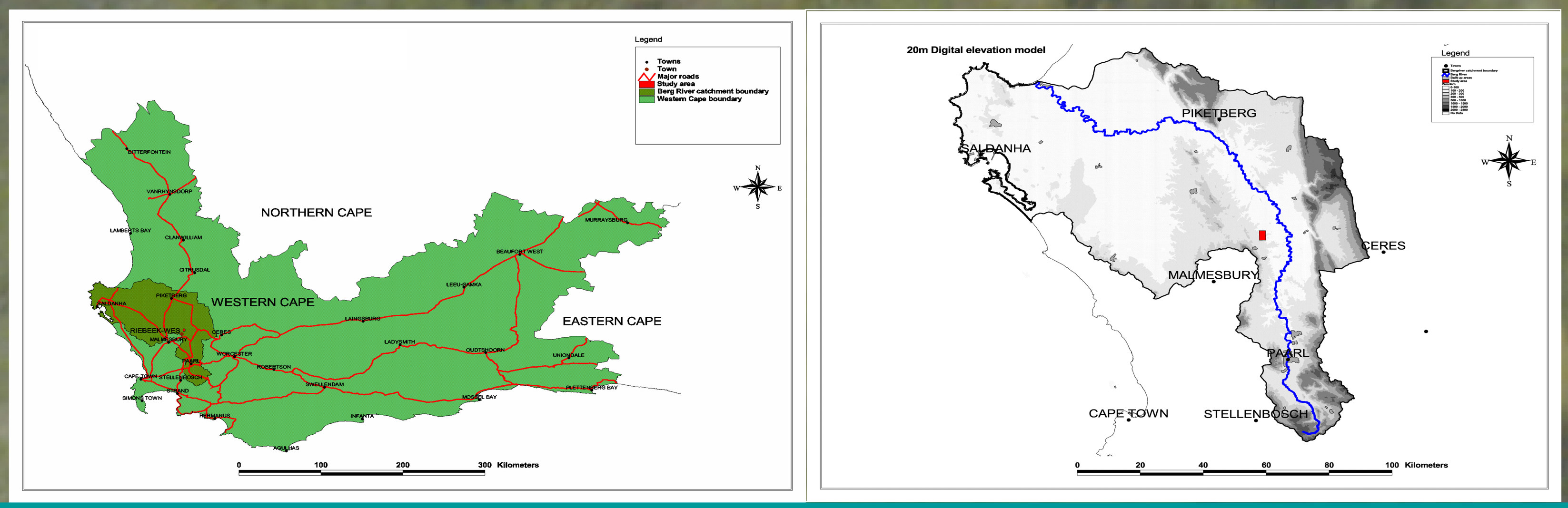

Figure 1: Location and 20 m Digital Elevation Model of the Berg River basin. The red square indicates the approximate position of the intensive monitoring sites

A cycle of research is currently under way to mitigate dryland salinization of the Berg River (Fey and De Clercq, 2004; Görgens and De Clercq, 2005; De Clercq et al., 2010). The hypothesis is that enhanced mobilization and discharge of these salts occurred by clearing natural vegetation and pasture land to make space for agricultural production (*Figure 2*).

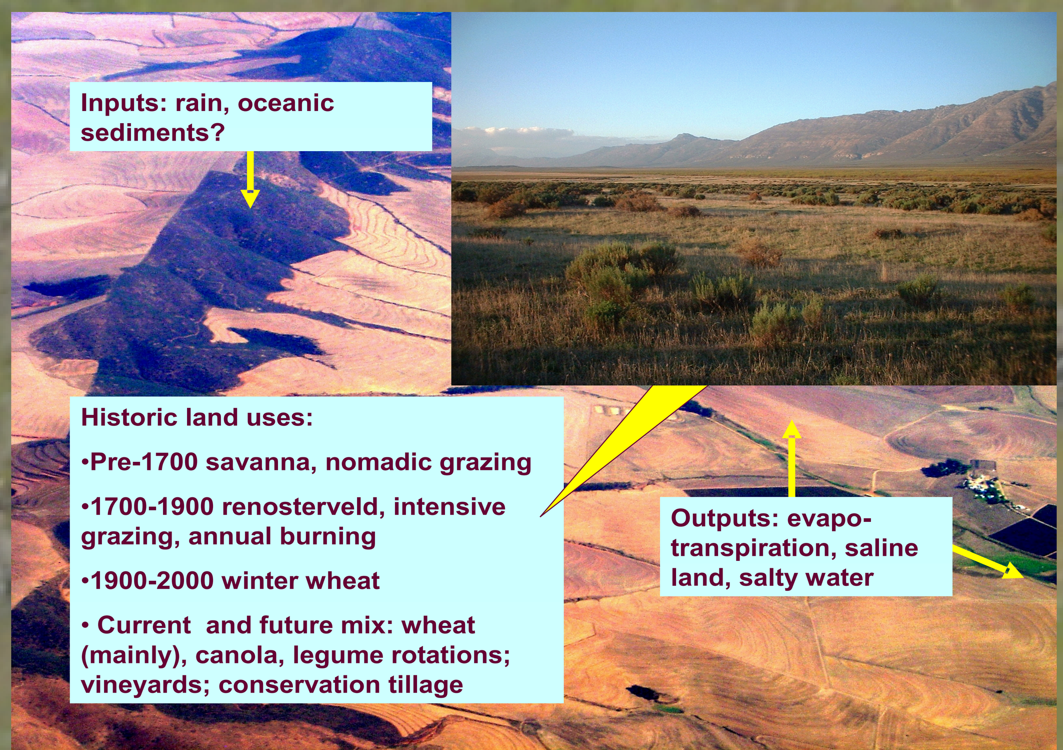

Figure 2: Schematic representation of sources and outputs of salt, and historic overview of land uses

Approach

Intensive monitoring at three experimental sites (*Figure 3*):

1) Langgewens experimental station: water and salt balances of different crop rotations

2) Goedertrou small scale catchment: hydrosalinity fluxes

3) Voelvlei Nature Reserve: evapotranspiration of endemic renosterveld vegetation and adjacent wheat field

The results obtained from the intensive monitoring sites served to inform hydrological modelling of salinity in the Sandspruit River (150 km² catchment), a saline seasonal tributary of the Berg (*Figure 3*)

A database was compiled for the Berg River basin: soil and geology, climate, hydrology, hydrogeology, water quality, vegetation and land use.

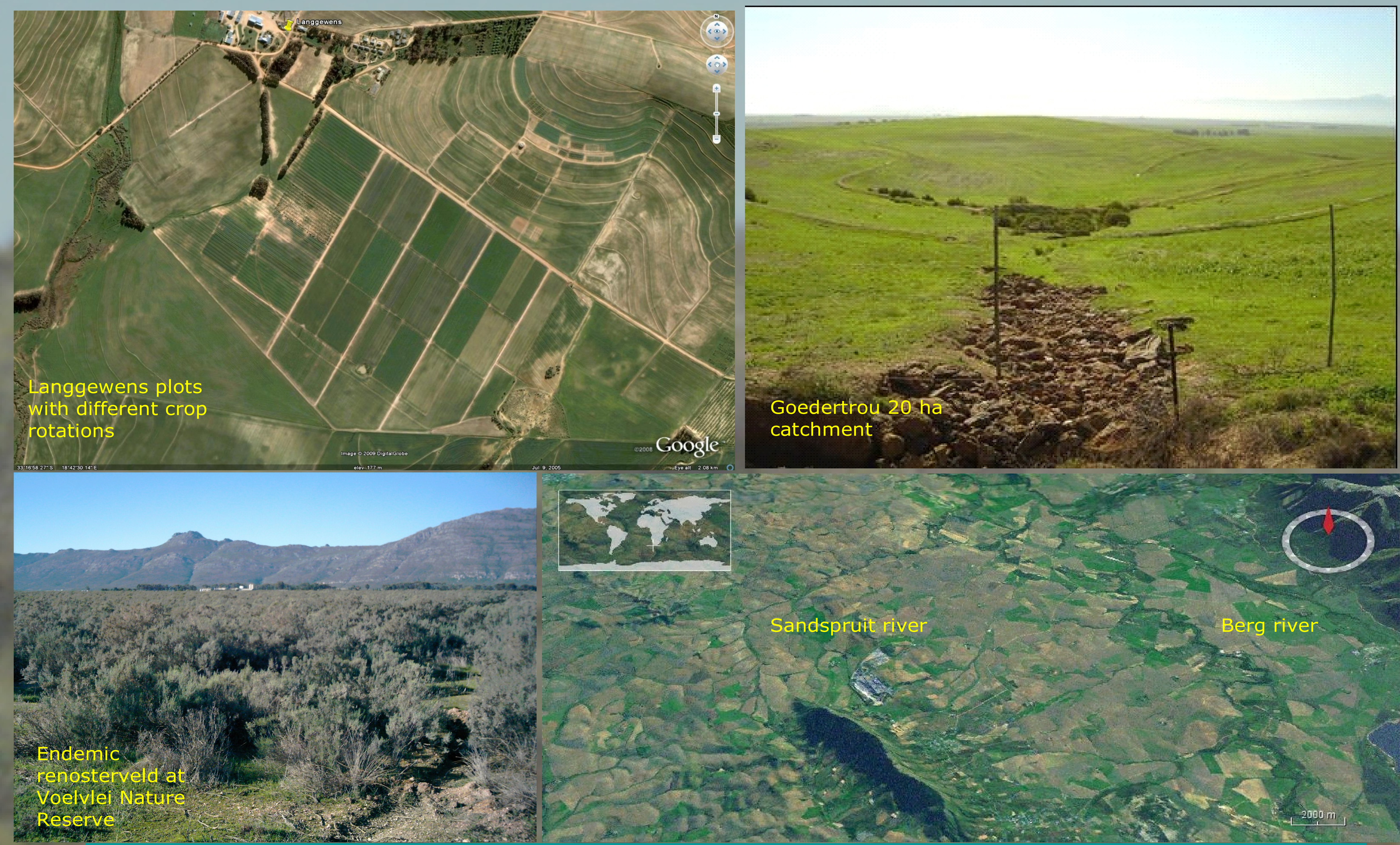

Figure 3: Overview of intensive monitoring sites and study catchment

Results

Mineralogical analyses brought evidence that oceanic salts were deposited via rainfall in geological ages when climatic and vegetation conditions were different from the present conditions. Concentration of these meteoric salts through evapotranspiration resulted in a gradient of groundwater salinity as an inverse function of annual rainfall (groundwater quality becomes increasingly saline from the recharge area at the top of the Berg River basin towards the bottom, semi-arid area of the basin, up to > 2,000 mS m^{-1}) (*Figure 4*).

Salts accumulated in bulges in the regolith above groundwater, flushed downwards by infiltration and recharge, and transported upwards from the groundwater table by capillary rise (*Figure 5*).

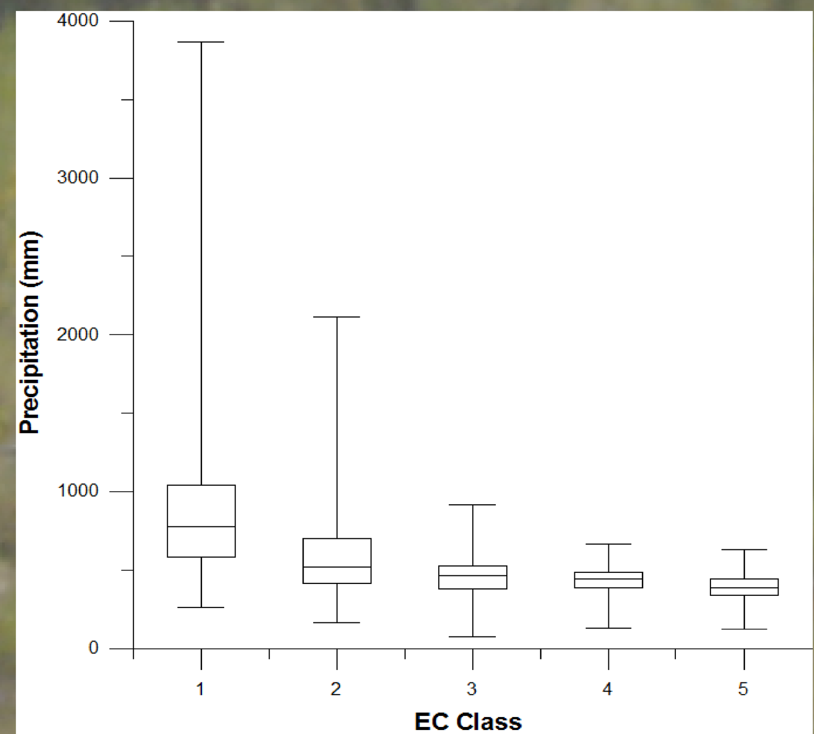

Figure 4: Relationship between mean annual precipitation and groundwater salinity (electrical conductivity EC class increases with increasing salinity) (Berg River basin)

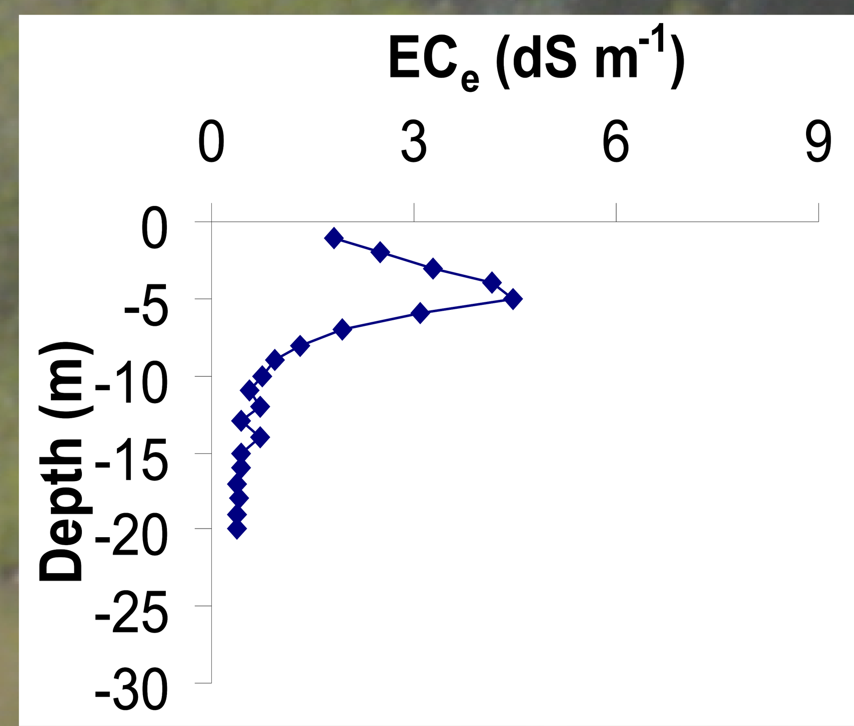

Figure 5: Electrical conductivity of saturated paste extract of regolith material as a function of depth (Goedertrou monitoring site)

Peaks of salt loads in runoff were generally measured in the middle of the rainy winter season, when the wettest conditions occurred (Figure 6). Annual salt load in runoff was between 0.016 and 0.236 t ha^{-1}, depending on annual rainfall, land use and management, and soil type. Bulk atmospheric deposition accounts only for a portion of the mass of salts discharged (Flugel, 1995). The remaining salt output is accounted for by groundwater and interflow from the weathered shale and the soils within the catchment.

Different land uses (e.g. indigenous vegetation, crop rotations etc.) greatly affect the water and salt balance of the system. In particular, endemic, well-established renosterveld with a deep rooting system was shown to transpire more than a wheat monoculture throughout the year (Figure 7). This has implications to the control of salt release, as groundwater tables in annual cropping systems are likely to raise, mobilize salts trapped in the regolith and enhance salt discharge.

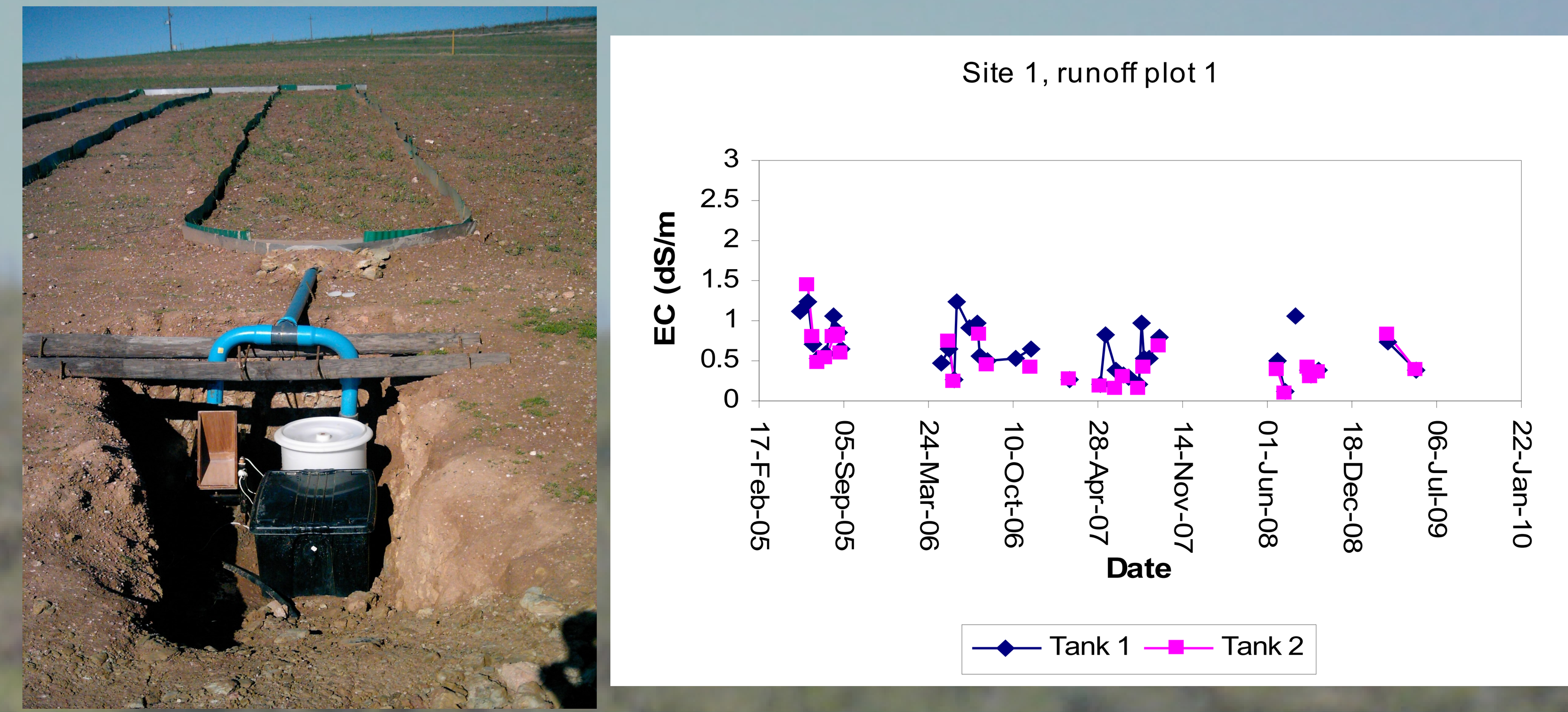

Figure 6: Electrical conductivity (EC) of overland flow collected in tanks from a standard Wischmeier runoff plot (Goedertrou monitoring site)

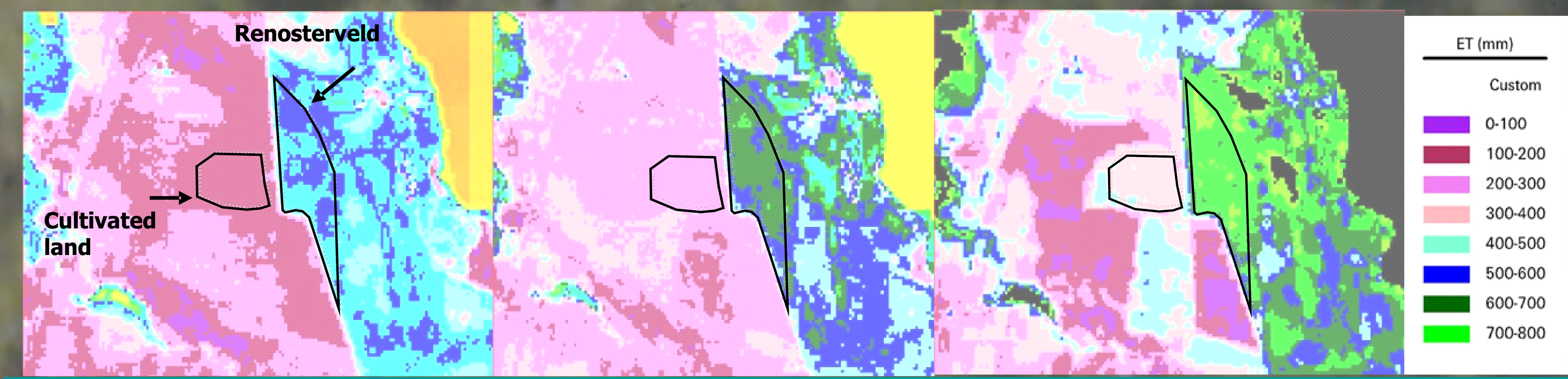

Figure 7: Spatial annual total evapotranspiration estimated for renosterveld and cultivated land with LandSat images and SEBAL (Surface Energy Balance Algorithm for Land) (Bastiaanssen et al., 1998) for three climatically different years (Voelvlei monitoring site)

Field monitoring served to generate data sets for hydrological modelling. Hydrological models were then used to quantify impacts of different land uses and management on salt dynamics and discharge into water resources:

PRMS (OMS framework, United States Geological Survey)

J2000 (JAMS framework, Friedrich Schiller University of Jena)

Discussion and Policy implications

The results of field investigations and modelling yielded new insights into the origin of salts and the behaviour of the system. A striking similarity exists between the mechanisms of salinization in the Berg River basin and those occurring in Australian catchments and other parts of the world. Human-induced salinization can be mitigated by manipulating the water and salt balances. Scenario hydrological modelling is currently being used to develop land use and management systems that would reduce salt loads in the Berg River (e.g. introduction of new cropping systems, planting renosterveld strips or high water-consuming trees, shallow tillage etc.). Predictive modelling is used to assess how long it will take for salts to be leached out of the system and at what rate. The research will result in the development of guidelines for regulating land use in terms of salt generation capacity to be adopted by the South African Department of Agriculture.

References

BASTIAANSSEN WGM, MENENTI M, FEDDES RA and HOLTSLAG AAM (1998) A remote sensing surface energy balance algorithm for land (SEBAL). 1. Formulation. *Journal of Hydrology* **212-213** 198-212.

FEY MV and DE CLERCQ WP (2004) Dryland Salinity Impacts on Western Cape Rivers. Water Research Commission Report No. 1342/1/04, Pretoria, South Africa.

FLUGEL WA (1995) River salination due to dryland agriculture in the Western Cape Province, Republic of South Africa. *Environment International* **21(5)** 679-686.

GÖRGENS AHM and DE CLERCQ WP (2005) Summary of Water Quality Information System and Soil Quality Studies. Water Research Commission Report No. TT252/05, Pretoria, South Africa.

DE CLERCQ WP, FEY MV and JOVANOVIC N (2010) Land Use Impacts on Salinity in Western Cape Waters. Water Research Commission Report No. K5/1503, Pretoria, South Africa. In press.

Acknowledgements

South African Water Research Commission, National Research Foundation, Department of Agriculture, Department of Water Affairs, and German Federal Ministry for Education and Research (BMBF) for funding, SA Rock Drill, Caren Jarmain (University of KwaZulu Natal), University of the Western Cape, farmers, United States Geological Survey