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UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

The environmental impact and sustainability of irrigation with coal-mine water

by

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Submitted in partial fulfilment of the requirements for the degree of
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DECLARATION

I, the undersigned, declare that the thesis which I hereby submit for the degree of Doctor of Philosophy at the University of Pretoria, is my own work, except where acknowledged in the text, and has not previously been submitted for a degree in any form at this or any other tertiary institution

Yacob Ghebretinsae Beletse

May 2008

This thesis is dedicated:

To the glory of God and in thanks giving for my many blessings.

"Thus far has the lord helped us…Ebenezer" 1 Samuel 7:12

To my beloved son Israel and my wife Tsedal Tseggai:

You are God's gift to me.

"Every good gift and every perfect gift is from above…" (James1:17)

To my dear parents:

I hope that this achievement will complete the dream that you had for me all those many years when you chose to provide me with the best education you could.

"Children, obey your parents in the lord, for this is right…

and that you may enjoy long life on earth" Ephesians 6:1-3

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" …with God all things are possible" Mathew 19:26

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THE ENVIRONMENTAL IMPACT AND SUSTAINABILITY OF IRRIGATION WITH COAL-MINE WATER

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ABSTRACT

The environmental impact and sustainability of irrigation with coal-mine water was investigated from an agricultural point of view on different coal-mines in the Republic of South Africa. Field trials were carried out on a commercial and plot scale, on sites that could offer a range of soil, crop, weather conditions and water qualities such as gypsiferous, sodium sulphate and sodium bicarbonate waters. Crop production under irrigation with gypsiferous mine water is feasible on a field scale and sustainable if properly managed. No symptoms of foliar injury due to centre pivot sprinkler irrigation with gypsiferous water were observed. The presence of high Ca and Mg in the water suppressed plant uptake of K. This could be corrected by regular application of K containing fertilizers. The bigger problem experienced was waterlogging due to poor site selection, especially during the summer months. The problem is not related to the chemistry of the gypsiferous water used for irrigation. Pasture production with Na_2SO_4 rich mine effluent was also feasible, at least in the short term, but

would need a well-drained profile and large leaching fraction to prevent salt build up. Forage quality was not affected by the Na_2SO_4 water used. $NaHCO_3$ water was of very poor quality for irrigation and is not recommended for irrigation. Salt tolerant crops that are not susceptible to leaf scorching can be produced with this water, but only with very high leaching fractions and careful crop management. Regular gypsum application will be required to prevent structural collapse of the soil. Most of the salts applied will leach from the soil profile, and will probably need to be intercepted for treatment or reuse. The Soil Water Balance (SWB) model was validated successfully. The model predicted crop growth, soil water deficit to field capacity and soil chemistry reasonably well, with simulated results quite close to measured values. Soluble salts have to be leached from the soil profile, so that crop production can be sustainable, but will externalize the problem to the receiving water environment. To assess the environmental impact of irrigation with coal-mine water, it is valuable to develop a tool that can assist with prediction of offsite effects. SWB was validated for runoff quantity and quality estimations, and was found to give reasonable estimates of runoff quantity and quality. SWB also predicted the soil water and salt balance reasonably well. This gives one confidence in the ability of the model to simulate the soil water and salt balance for long-term scenarios and link the output of SWB to ground and surface water models to predict the wider impact of large scale irrigation. This will also link the findings of this work to other research oriented towards the management of mine water and salt balances on a catchment scale. It will also help authorities make informed decisions about the desirability and consequences of permitting mine water irrigation on a large scale. Irrigation with gypsiferous mine water can be part of finding the solution to surplus mine water problems. Appropriate irrigation management of mine water is essential for the long-term sustainability of irrigation.

Key words: Coal-mine water, irrigation, SWB model, modelling, soil salinity, $CaSO_4$, gypsiferous water, Na_2SO_4, $NaHCO_3$, sustainability, environmental impact

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LIST OF SYMBOLS AND ACRONYMS

AMD	Acid Mine Drainage
CBM	Coal bed methane
CEC	Cation Exchange Capacity
D	Wilmot's index of agreement
DOY	Day of the year
DRIS	Diagnosis and Recommendation Integrated Systems
EC	Irrigation water salinity
EC_e	Soil saturated paste extract
EC_{iw}	irrigation water salinity
ESP	Exchangeable Sodium Percentage
ET	Evapotranspiration
HDM	Harvestable Dry Matter
HDM	Harvestable Dry Matter
LAI	Leaf Area Index
LF	Leaching Fraction
LR	Leaching Requirement
MAE	Mean Absolute Error
r^2	Coefficient of determination
RD	Root Depth
RMSE	Root Mean Square Error
SAR	Sodium Adsorption Ratio
SCS-CN	Soil Conservation Services Curve Number
SD	Standard deviation
SR	Sufficiency Range
SWB	Soil Water Balance
TDM	Top Dry Matter
TDM	Top Dry Matter
TDS	Total dissolved salts
WFDs	Wetting Front Detectors