# Soil chemical and nutrient uptake dynamics of maize (*Zea mays* L.) as affected by neutralization and re-acidification after liming

by

Hester Getruida Jansen van Rensburg

Thesis submitted in partial fulfillment of the requirements for the degree Doctor of Philosophy
in Soil Science
in the
Faculty of Natural and Agricultural Sciences
University of Pretoria
Pretoria

October 2009

Supervisor: Prof A S Claassens
Co-Supervisor: Dr D J Beukes

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Declaration

I, the undersigned, hereby declare that the work contained in this thesis is entirely my own original research, except where acknowledged, and that it has not at anytime, either partly or fully, been submitted to any University for the purposes of obtaining a degree.

Signed: ________________________ Date: __________________________

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

# TABLE OF CONTENT

# TABLE OF TABLES

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

# TABLE OF FIGURES

# TABLE OF MAPS

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

# ABSTRACT


An imperative of the South African government is to increase agricultural production in rural areas. In support of this, a project was initiated in the Mlondozi district of Mpumalanga Province under the National LandCare programme. The goal was to assess land management practices contributing to sustainable and profitable agricultural production. Medium-term liming experiments were sampled to a range of lime treatments in a Hutton and Oakleaf soil. Critical thresholds where a reduction in relative grain yield was found were at a pH ($H_2O$), extractable acidity, Al and acid saturation of 5.49, 0.277 $cmol_c$ kg $soil^{-1}$, 0.145 $cmol_c$ kg $soil^{-1}$ and 13%, respectively. Critical soil fertility threshold levels were established at 50 mg K $kg^{-1}$, 228-345 mg Ca $kg^{-1}$, 78-105 mg Mg $kg^{-1}$ and 1.68-2.83 mg Cu $kg^{-1}$. Nutrient vector analysis showed a toxic build-up of Fe, followed by Al and to a lesser extent Mn, which depressed the uptake of Ca, Mg and B in the Hutton soil. In the Oakleaf soil, Al toxicity, followed by high concentrations of Mn and Fe, markedly reduced the uptake of Ca, Mg and K by maize. Net rates of acid production in the soil profile varied between 1.61 and 2.44 kmol $H^+$ $ha^{-1}$ $year^{-1}$ for the Hutton soil and between 4.59 and 8.82 kmol $H^+$ $ha^{-1}$ $year^{-1}$ in the Oakleaf soil due to liming. A decline of 0.046 pH unit $year^{-1}$ for an initial pH($H_2O$) value of 5.33, and 0.140 pH unit $year^{-1}$ for an intial pH($H_2O$) of 6.47, respectively, in the Hutton was recorded. For the Oakleaf these declines were 0.044 and 0.110 pH unit $year^{-1}$, from pH($H_2O$) 4.54 and 5.15. Maintenance liming amounts at different pH values for the Hutton soil were equivalent to 0.2, 0.3 and 1.4 tonnes $CaCO_3$ $ha^{-1}$ annually, while 0, 0.8 and 0.8 tonne $CaCO_3$ $ha^{-1}$ annually were recorded for the Oakleaf soil.

The study was extended to 80 random topsoil samples in the district. Relationships of soil BC over limited pH ranges showed that at soil $BC_{(pH<4.5)}$ the main buffering mechanism was extractable Al > organic C > clay. At soil $BC_{(pH4.5-6.5)}$ the buffering mechanism was extractable Al > clay > CBD-Al > organic C > CBD-Fe. The main buffering mechanism between pH 6.5-8.5 was clay > CBD-Fe, organic C > CBD-Al. Acid production for 30 crop production sites varied from a measured 0.21 to 10.31 (mean 3.70) kmol $H^+$ $ha^{-1}$ $year^{-1}$ The rate of pH decline for the top 0-250 mm depth was between 0.051 and 0.918 (mean 0.237) pH units $year^{-1}$. In the absence of remedial lime applications, pH ($H_2O$) values in most of the area are projected to decrease to the critical value of 5.68 or lower within 4 years. Soil with a pH ($H_2O$) value of >5.73, extractable Al and acidity of <0.18 and <0.25 $cmol_c$ $kg^{-1}$ soil, respectively, clay content of ≤26%, and a ECEC value of ≤3.29 $cmol_c$ kg $soil^{-1}$, are at greater risk of acidification as gradual acceleration in soil acidification takes place at the above-mentioned critical thresholds.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

# ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to the following persons and institutions:

Professor Andries S Claassens and Dr Danie J Beukes, for their mentoring and guidance, and for their assistance in the preparation of this manuscript.

In addition, special thanks to Mr Leon de Beer and other extension staff of the Mpumalanga Department of Agriculture and Land Affairs.

Appreciation is expressed to Mr Filemon Mathunjwa and Mr Claas Zwane for donating the experimental sites and for logistical support.

My thanks to Mrs Marie Smith for statistical analyses.

The Agricultural Research Council and the National Department of Agriculture for funding.

Mr Simon Tshabalala, Charles Maseko, Catherine Nkosi and Eric Mashabane, extension officers in Mlondozi, for their assistance and advice.

Mr Marius van Rensburg from the Nooitgedacht Agriculture Development Centre for his assistance and advice.

Mr Michael Kidson, Mr Martiens Mmamadisha, Mr William Mashabane, Ms Rinda van der Merwe, Mr Roelof le Roux, Mrs Petro Ströhmenger, Mr Bates Booyens, Mr Louw Potgieter and Mr Willem Kirsten, from the ARC–Institute for Soil, Climate and Water, for their willingness and hard work in the execution of the project.

Mrs Esmè Lazenby and Mrs Anastasia Kgapane (ARC-ISCW) for research support with the demonstration trials at Mlondozi.

Dr Thomas Fyfield (ARC-ISCW) for editing this report.

My husband, Stephanus, and children, Carli and Mieke, my family and friends for their support and motivation.

Abba Father for guidance, perseverance and wisdom, to you Father the highest praise.