CAN SPATIAL DISTRIBUTION AND CANOPY SPECTRAL REFLECTANCES OF A PHREATOPHYTE TREE (*RHUS LANCEA*) BE USED TO IDENTIFY DEVELOPING SINKHOLES AND ACID ROCK DRAINAGE IN A DOLOMITIC GRASSLAND?

Chauke, J[1*], Weiersbye, I.M.[1], Stark, R. (Dr)[2], Margalit, N.[2], Nel, H.J.[3], Feingersh, T. (Dr)[2], Revivo, G. (Dr)[2], Zur, Y., (Dr)[2] and Braun, O.[2]

[1]University of the Witwatersrand, Johannesburg, South Africa, [2]Elbit Systems Electro-Optics ELOP Ltd, Israel; [3]AngloGold Ashanti Ltd. [*]Presenting author: c/o isabel.weiersbye@wits.ac.za

ABSTRACT

The Highveld dolomitic grasslands fall within the Witwatersrand Basin gold and uranium mining region of the Grassland Biome, and only a small fraction is conserved. Sinkholes, areas where the finer particles are eroded away from around dolines in dolomitic substrata over thousands of years, are a natural feature of Highveld dolomitic grasslands. The depressions may act as `safe-sites' for some plant species, and as refugia for small animals, and old sinkhole depressions are associated with a characteristic flora that often includes the evergreen phreatophyte tree *Rhus lancea*. Gold mining activities that can potentially increase the rate of sinkhole formation include the dewatering of substrata, the release of large volumes of water through doline landscapes, and the release of acid rock drainage (ARD). It is therefore important to identify areas which may be impacted in the future by sink-hole formation, and to designate appropriate low-risk land-uses. Potential land-uses include areas for biodiversity conservation where developments are avoided, and, for the ARD-impacted soils immediately around mine tailings storage facilities (TSFs), the planting of woodlands of native savanna trees, including *R. lancea*, in order to capture ARD before it can enter groundwater and streams.

Our objectives were to determine whether, (a) *R. lancea* spatial distribution and (b) leaf water content in winter is positively associated with developing or visible sinkholes, and, (c) if foliar pigment vegetation indices (VI's) of productivity and stress are associated with groundwater depth, quality, or foliar elemental-concentrations. Even though previous aerial photograph studies have shown patterns of vegetation associated with visible depressions, no specific vegetation type or species has been used as cue for developing sinkholes. These objectives are therefore of value in identifying dolines or other conduits, to indicate the relative quality of groundwater in the vicinity of the conduit, and to provide a baseline for monitoring the long-term impacts of conservation and woodland land-uses on substrate stability and landscape hydrology.

We plotted the positions of evergreen trees visible in a high resolution colour aerial photograph of the Vaal River mining property (~12 000 hectares; S26° 53'.743" E26° 45'.557") which are taken in winter 2004 on ArcGIS v9.2 (ESRI™) in relation to surface geology, and the position of 2311 known and

suspected sinkholes. The position of known (visible and historically backfilled) sinkholes was obtained from field observations by AngloGold Ashanti Ltd, from historical aerial photographs (1940's to 1950's), and for suspected sinkholes, from airborne thermal radiometry. Data for depth to groundwater and groundwater quality parameters (pH, Eh, sulphate concentration and total dissolved solids (TDS) concentration) was provided for 102 georeferenced monitoring boreholes by AngloGold Ashanti Ltd, and the mean depth and quality parameter calculated for the three closest boreholes to each tree (a distance of >10<100m for each borehole). Trees within 10m of monitoring boreholes and trees within 50 metres of the riparian woodland zone of the Vaal River were excluded from the analyses. Foliar reflectance spectra were acquired from three bulked leaf samples per tree for 55 of the *R. lancea* trees growing on dolomitic grassland in August (Austral winter) 2005 and August 2007 using a hand-held analytical spectral device (ASD Inc., Boulder, Colorado, USA). At the same time in August 2005, airborne hyper-spectral remote sensing with an AISA-ES sensor in the spectral range of 403-2370nm and with an average spectral resolution of 10nm was conducted over the entire polygon at 21,000 fagl (resulting in a 3.3m pixel spatial resolution). Several signature targets were used for atmospheric calibration. Thematic imagery of VI's for evergreen tree canopies were derived from the atmospherically corrected data. The *R. lancea* samples were assessed for leaf water content by mass loss on drying, pigments by solvent extraction and spectroscopic analysis, and elemental concentrations by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and ICP Mass Spectrometry (ICP-MS) of acid dissolutions against the Orchard Leaf 1570 standard reference (NBS).

Four complementary indices were derived from the foliar spectral reflectances, i.e. the Normalised Difference Water Index (NDWI) to assess *R. lancea* canopy liquid water, the Normalised Difference Vegetation Index (NDVI) to measure general canopy vigour, the Red Edge NDVI (R695/R670) for sensitive detection of canopy stress, and the Plant Senescence Reflection Index (PSRI) to maximize detection of bulk carotenoid to chlorophyll ratios. For treatment effects, statistical significance was taken at the 5% level, with the Bonferoni adjustment used for multiple comparison tests. Standardised (Pearson) residuals and odds ratios were used to examine the lack of independence, and regression analysis used to test for association between VIs and groundwater depth, quality and foliar chemistry in Statistica 6.0.

There was no difference found for tree canopy VIs between August 2005 and August 2007. Spatial analysis indicated that irrespective of depth to groundwater, areas with sinkholes supported a higher density of *R. lancea* trees than areas without sinkholes (N=1923, X^2 = 955.7087, $P<0.05$), possibly due to constant water supply all year round. *Rhus lancea* canopy VI's were however not affected by depth to groundwater (from 2 to 12 mbgl) or groundwater quality, which ranged from 200 to 6000 mg/l TDS.