VERY HIGH SPATIAL AND SPECTRAL RESOLUTION REMOTE SENSING IN MINING-RELATED ENVIRONMENTAL ASSESSMENT OF THE WITWATERSRAND GOLD FIELD

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1. INTRODUCTION

This paper presents most significant results of the work carried out in the frame of a ten-year scientific collaboration between BRGM (the French Geological Survey) and the Council for Geoscience of South Africa. The collaboration aimed at developing remote sensing and GIS-based integrated approaches for assessing and monitoring the environmental impact of the gold and uranium mining over the Witwatersrand gold field.

A wide panel of Earth Observation techniques were simultaneously used for these studies, including conventional sensors (Landsat TM, SPOT) high spectral resolution satellite imagery (ASTER, Hyperion), airborne radiometrics and various in situ measurements (pH, Eh, conductivity, portable Niton XRF…).

2. THE WITWATERSRAND GOLD FIELD

The Witwatersrand goldfield, located in the immediate vicinity of Johannesburg has been mined for more than a century. It is the world's largest gold and uranium mining basin with the extraction, from more than 120 mines, of 43,500 tonnes of gold in one century and 73,000 tonnes of uranium between 1953 and 1995 [1]. The basin covers an area of 1600 km², and led to a legacy of some 40,000 ha of mine tailings dams [2], among them the largest in the world and 6 billion tonnes of pyrite tailings containing low-grade uranium (U) [3]. The Witwatersrand mining basin is composed of several distinct mining areas, namely the Far East Rand Basin, Central Rand Basin, Western Basin, Far Western Basin, Klerksdorp (KOSH) area and the Free State Goldfields thus affecting a considerable area and large watersheds.

Regarding the very large extent of this mining basin, remote sensing brings an invaluable contribution in mapping areas affected, or potentially affected by mining activities.

3. ENVIRONMENTAL AND SOCIETAL ISSUES

Huge amount of tailings dams, waste rocks and derelict lands potentially cause severe regional environmental problems, including acid mine drainage and the dissemination of toxic materials (naturally-occurring radionuclides, heavy metals, dissolved salts and process reagents) into the environment. In many cases and since the mid-1980s, tailings dams are being reprocessed for residual gold extraction using cyanide process.

Furthermore, the Central Rand, East Rand and West Rand are situated in highly urbanised areas and present a potential high-risk level due to rapid urbanisation and/or and agricultural development in an area largely occupied by extensive tailings facilities.

4. APPROACH

A simplified conceptual contamination model, based on the source – pathway – receptor (SPR) paradigm has been developed to perform risk assessment.

Figure 1 shows the main tasks in environmental assessment and management following the SPR concept and the best suited sensors to perform them.

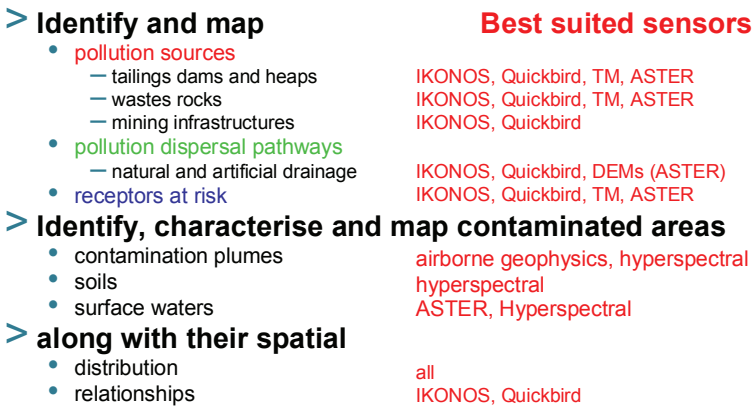

Figure 1: Potential of remote sensing assessment tools in an environmental management perspective

Both image visual interpretation and digital image classification approaches have been used. Resulting maps have been exported as GIS layers, which attributes were recoded and/or combined to perform environmental assessments.

5. MAJOR RESULTS

Very-high resolution brings an invaluable contribution in mining-related environmental management. Very-high spectral resolution can contribute to the characterisation and mapping of mineralogical or chemical composition of soils and wastes, status of the vegetation, surface water contamination, land-cover mapping of mining areas. Very-high spatial resolution images enable the extraction and mapping of the major components and surface features relevant of environmental management, from local (site) to regional scale and their spatial relationships, making thus possible the production of contamination and health risk maps. A major contribution lies also in monitoring tailings facilities and mining infrastructures physical stability.

Very-high spatial resolution images have proven invaluable contribution in preliminary checking of the validity of lower resolution image classification. Image segmentation and texture analysis enable avoiding confusion between spectrally identical objects.

The complementarity of these techniques, once integrated into GIS and combined with other relevant data, enables to perform modeling impact or contamination pathways and/or propose valuable information for site remediation or rehabilitation.

Eventually, a methodology for a risk-based prioritisation of tailing waste facilities using Remote Sensing and GIS has been proposed and applied to the whole Witwatersrand [4].

6. REFERENCES

[1] Wilson, M.G.C. and Anhaeusser, C. R. (eds) (1998) The Mineral Resources of South Africa: Handbook, Council for Geoscience, 16, 740 p

[2] Robb, L. J. and Robb, V. M. (1998) Gold in the Witwatersrand Basin. The Mineral Resources of South Africa, sixth Edition. M. Wilson and C. Anhaeusser. Pretoria, Council for Geoscience**:** pp. 294-349.

[3] Wymer, D. G. (2001) The impact of gold mining on radioactivity in water and foodstuffs. Conference on environmentally responsible mining in South Africa. Chamber of Mines of South Africa. Muldersdrift. 1**:** pp. 2C-19-2C-30

[4] Chevrel, S., Croukamp, L., Bourguignon, A., Cottard, F., Gibbson, L., Boon, D., (2006) Detecting and defining the risks in the Witwatersrand gold field, Inventory and risk-based prioritisation of tailing waste facilities using Remote Sensing and GIS, Witwatersrand Goldfield, South Africa, in Mining Environmental Management, July 2006, pp 26-30