GAMMA-RADIOMETRICS: A REMOTE SENSING TOOL FOR UNDERSTANDING SOILS.

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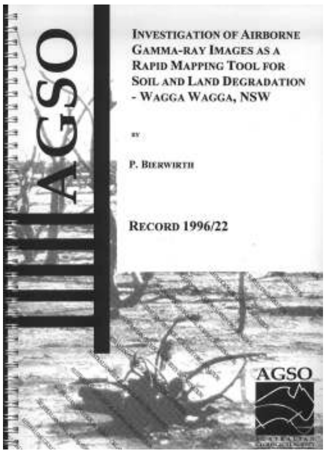
In recent years, airborne gamma-ray spectrometry (AGS) has become a recognised tool for soil and regolith mapping (Wilford, 1992, Cook et al., in press). However, there are still a lack of definitive studies that scientifically assess the information content of gamma-ray derived data. The question is: how do the gamma-radiometric patterns relate to soil properties and how can this data be used to assist with or improve soil mapping? This is the subject of a new AGSO record (Bierwirth, 1996; see cover below),



The record is a product of the collaborative study ‘Developing Spatial Analysis Methods for Land Resource Assessment’, funded by the Murray Darling Basin Commission, involving AGSO, CSIRO Division of Soils (Canberra), NSW Department of Land and Water Conservation (DLWC) and ANU Centre for Resource and Environmental Studies (CRES) and conducted in the Wagga Wagga region.

Airborne gamma spectrometry

AGS measures geochemistry, i.e. the spatial distribution of elements potassium (K), thorium (Th) and uranium (U) in the top 30-45 cm of the surface layer. The abundance of K, Th and U in near-surface materials are measured by detecting the gamma-rays produced during the natural radioactive decay of isotopes of these elements. The measurement of particular wavelengths makes it possible to determine the quantities of various isotopes and since gamma-rays are strongly attenuated in rocks, soil and air, most of the radiation emanates from shallow ground depth. While the gamma-ray counts are dampened by soil moisture and vegetation, these effects are generally minor.

The AGSO acquisition system collects a gamma-ray spectrum at points, spaced approximately 70m apart, along ground profiles. In recent surveys these profiles or lines are evenly spaced at 200 metres apart. To capture enough signal, an aircraft must fly at low altitude generally at a maximum of only 120 metres. Significant overlap between sample points along a profile occurs due to the large 'footprint' - 50% of received gamma-rays emanate from an area of 180 metres in diameter. The measured gamma spectra are then processed to derive abundances for the three elements together with a total count. The point values are interpolated to form a grid

of values which can be displayed as an image of the region surveyed. During airborne AGS surveys, magnetic field intensity and elevation of the terrain traversed, are also recorded.

Ground measurements and sampling

For the Wagga Wagga study airborne gamma-ray measurements were compared with 1) a large number of samples analysed for soil properties including K, U and Th contents, 2) many ground gamma-spectrometer measurements, 3) terrain attributes derived from DEM modelling (Gessler, 1996) and 4) soil-landscape mapping (Chen and McKane, 1996). Detailed study sites were established in 1) hilly areas of metasediment basement geology (Ladysmith area) and 2) a flat area of deep alluvium (Bullenbong plain). The first site was also reflown with a small area being covered with a 100m line-spaced AGS survey.

Gamma element distribution - parent material or pedogenesis?

While AGS data has been used by AGSO and exploration company geologists for decades to delineate bedrock mineralogy and geochemical alteration, there has been little focus on gamma-ray patterns in areas of deep soils. At Wagga Wagga, bedrock mineralogy clearly influences the signals where there are shallow lithosols and except for sandstone areas, gamma-element abundances are generally high. On some colluvial slopes and active alluvial areas, transported parent material is observed in the images. However, when both the regional samples and the Ladysmith study area samples were analysed with respect to landscape position, evidence for pedogenic effects on gamma-element abundances was discovered.

Soil landscape units, based on geology and landform, generated by the NSW DLWC (Chen and McKane, 1996) were used to separate the sample data. One unit category, ‘piedmont terraces and sloping plains’, includes interpreted basement geology types and represents areas where pedogenesis dominates erosion and deposition. In these areas there is a relationship in the sample data between total K and pH (Figure 1).

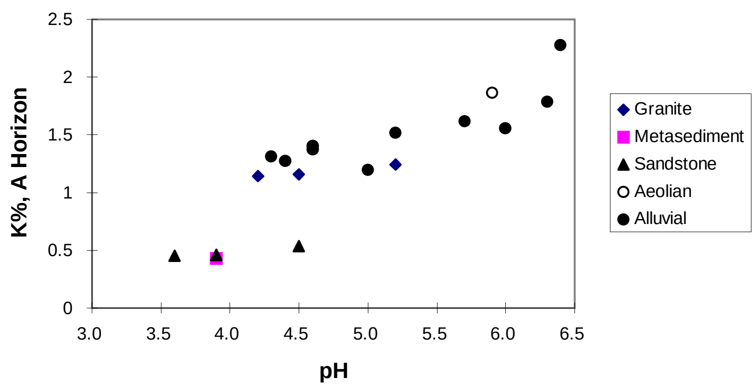


Figure 1. Potassium versus pH for piedmont terraces and sloping plains.

In these geomorphically inactive areas, increased leaching results in low K and low pH. The patterns in the airborne K image are therefore strongly influenced by pedogenic processes. This indicates that in old landscapes, pH mapping may be possible using airborne K data. Parent material may still be an important factor (Figure 1) and the few points for the various

lithologies suggest multiple lines are present. A related but inverse relationship was also found between K and exchangeable aluminium.

Sample data in the Ladysmith study area to the east of Wagga Wagga also showed evidence of leaching as a control on K patterns. Figure 2 shows the hilly landscape in this area and AGS measured K concentrations and airborne derived terrain elevations are combined as a 3D perspective.

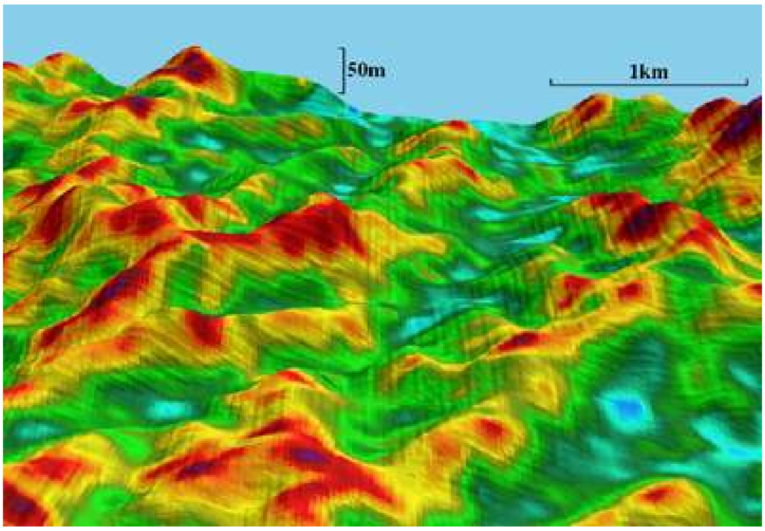


Figure 2. Airborne K content of shallow lithosols and colluvium (draped on elevation). Colour scale represents K content (red=high, blue=low)

At the tops of ridges, soils are shallow lithosols and the K concentration (about 3%) relates to mica in the bedrock. Downslope colluvial soils have developed to a thickness of about 2 metres and K is progressively removed (to < 1%). Sample data from Ladysmith showed that K concentration in the colluvium relates to leaching and the degree of development of a bleached A2 Horizon. Although thorium is less mobile, it also shows some loss downslope.

AGS data - a powerful tool in flat terrains

Gamma-ray data can be a significant mapping aid in the vast expanses of gentle, very low relief land requiring land resource survey in Australia. In these areas traditional mapping tools, i.e. landscape mapping and DEM analyses, become less useful.

On the Bullenbong plain to the west of Wagga Wagga, AGS data discriminated active alluvial areas with silty top soils (on the basis of K and Th values) Th values allow discrimination of gilgai, cracking versus non-cracking soils and parna. Low Th and U concentration appeared to relate to gilgai and the degree of cracking in the soils. Evidence suggests that this may relate to loss of radon in areas of intense cracking. Being generally immobile, Th was found the most useful element for mapping variations in parent material including palaeochannels.

Techniques for data analysis and classification

In most AGS data sets, the distribution of gamma elements relates to a mixture of factors relating to parent materials and pedogenesis. The study (Bierwirth, 1996) found that

interpretation of the data varies for different host geology and soil-landscape. Interpretation of individual AGS channels overlain on topographic information is a good starting point. Computer generated interpretations of AGS data should include the analysis of geology and digital terrain data. Wholesale classification of the multichannel data alone will produce a large number of assumed soil similarities that do not exist. Some workers go further and assume that soil chemistry can be related to AGS multichannel classification ‘classes’ and that soil pH, salinity and texture maps can be generated for a whole region from classified gamma-ray data alone (Gourlay, 1996). However in many areas, K shows pedogenic effects and Th reflects parent material. In such cases the patterns are not correlated and classification produces a confused mixture of the two effects. For classification to be useful, the data should first be divided into particular geomorphic or geological terrains. This should incorporate DEM modelling (Gessler, 1996) and might only involve a particular gamma element image. If one gamma element best defines soil properties related to mappable soil units, then inclusion of other elements, in a mapping model, may degrade the model.

Limitations

Although interpolation techniques to correlate between flight lines are likely to improve, there are accuracy limitations for the position of image pattern boundaries. For example, a discrete body of material between two flightlines will be shown in the image data as occuring under, and extending beneath, both flight lines. For a small area at Ladysmith, 100m spaced lines were flown and alternate lines were used to create separate 200m and 400m line-spaced surveys. In many areas, the comparison of the two simulated 200m surveys (gridded with a 50m pixel) showed a variation of boundary position of about 100 metres.

U and, to a lesser extent, Th images, are noisy due to low counts relating to the limitations of minimum aircraft speed and the size of the gamma-ray measuring crystal. This problem can be overcome marginally by using helicopters for airborne survey (though at considerably increased cost), and significantly by vehicle ground gamma spectrometric surveys.

Compared to satellite remote sensing technology, to acquire new data for an area, AGS surveys are relatively expensive. However, the availability of high resolution AGS data (i.e. already acquired and much cheaper), is increasing.

National AGS Coverage

There is an increasing amount of regional AGS coverage of high resolution (i.e. 500 m line spacing or less) airborne gamma-ray and magnetic data being acquired (AGSO, 1996). Large areas of rural NSW, Victoria and South Australia have been surveyed in the last 5 years, with the equivalent of 15 x 1:250,000 map sheets in NSW (including Forbes, Bathurst, Dubbo and Narromine) and 9 sheets in Victoria.

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