# HIGH-RESOLUTION GROUND BASED GAMMA-RAY SPECTROMETRY AND ELECTROMAGNETICS TO ASSESS REGOLITH PROPERTIES, BOOROWA, NSW

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## INTRODUCTION

The current economic, social and environmental climate sees constant pressure on land managers to merge greater agricultural production with sustainable land use practices. Throughout Australia's European history this has been a paradox, with the mistaken perception that the fertility of the Australian landscape and the supply of available resources are seemingly limitless. Evidence of land degradation emerged as early as the mid 1800s and by the early 1900s governmental agencies were addressing issues associated with land degradation. However, traditional farming practises still persisted for many years (Breckwoldt 1988). Today attitudes on the ground are slowly changing with the major limitations to implementing the final change for sustainable management practices being economic viability and sufficient information to make accurate and effective decisions (Charman & Murphy 2000).

Whilst it is the soil surveyor's aim to "*study, classify, describe and map soils so that predictions can be made about their behaviours for various uses and their response to defined management systems.*" (USDA 1950), the changing face of land management means that the traditional methods of mapping are fast becoming inefficient and inadequate. For the soil scientist, current survey methods are labour intensive, time consuming and typically require expensive analytical procedures. For the land manager the soil maps are not directly relevant and need skilled interpretation and complex decoding of the specific soil classification, beyond the realms of general agricultural use. A major limitation is the inability to decipher small-scale spatial soil variation due to the non-continuous nature of the sampling procedure that results in interpretive, generalized and pedologically defined soil type divisions.(McKenzie & Ryan 1999, McKenzie *et al.* 2000). Therefore, in order to encompass a user friendly, efficient, highly detailed and spatially accurate form of soil mapping, a complementary set of methodologies is required.

Remote sensing, GIS and spatial statistics are approaches that address these limitations but as yet accurate methods have not been established for property management level regolith mapping (McKenzie *et al* 2000). Current methods predominately involve airborne and satellite data using the reflective, thermal and infrared spectral signals such as Landsat Enhanced Thematic Mapper or Multispectral data (Barnes *et al.* 2003). However, recently there has been an increasing tendency towards the integration of airborne geophysical images in landscape interpretation and exploration such as radiometrics, magnetics and electromagnetic surveys as ground penetrating tools (Wilford 1997). Further, these tools are often at a scale too broad for detailed accurate interpretation needed by land managers. The solution to this has been the use of ground-based remote sensing tools, predominately spectrally based, with the exception of electromagnetics (Barnes *et al.* 2003).

This study examines the use of two high-resolution mobile geophysical tools: a ground based gamma-ray spectrometer (radiometrics); and electromagnetics (EM), for an initial assessment of highly detailed data for regolith mapping at Boorowa, NSW.

## STUDY AREA:

Boorowa is a grazing and cropping region located 100 km NW of Canberra in the Central West of New South Wales. Average annual rainfall ranges from 570 mm to 770 mm. The Boorowa River Catchment covers 1,820 km$^2$ in the headwaters of the Lachlan River, lies in the Palaeozoic Lachlan Fold Belt of South Eastern Australia, and is dominated by Silurian acid volcanics. Hydrological models in the catchment indicate the transmission of water via two aquifer zones:

i) The upper zones of shallow regolith/highly weathered material to about 10 m, which contains the major salt store; and

ii) The lower fractured rock system down to about 40 m (Evans *et al.* 1999).

The 2x1 km study area is located on the property "Allendale", 8 km north of Boorowa (Figure 1.a and 1.b). The geology consists of the Hawkins Volcanics—acid volcanic rocks composed of tuffs and ignimbrites. The major soil types, mapped at ca. 1:10,000 scale, consist of: Ferrosols – red, duplex, acid earths on hills; Chromosols - red and yellow, duplex podsolic soils; and, more Chromosols -yellow solodics and solodised solonetz on the valley floors. Salinity affects nearly 7% or 55 ha and many trees have been planted along hillslopes and drainage lines to alleviate the symptoms (Figure 1.b) (Elliot 1999).

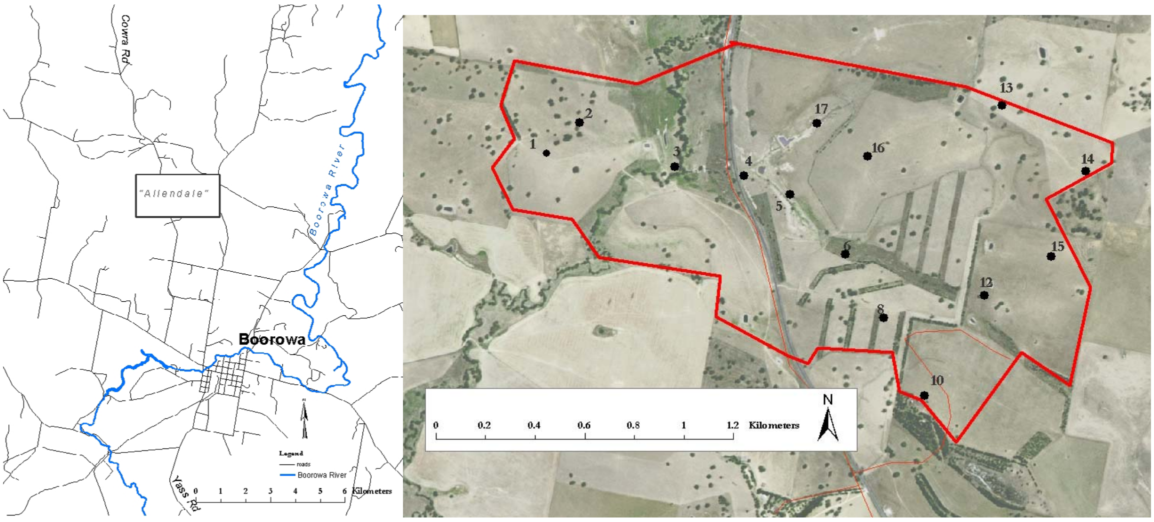



**Figure 1:** a) Study Area and Boorowa township. b) "Allendale" 25 m resolution SPOT image

## THE GEOPHYSICAL TOOLS:

Gamma-ray spectrometry measures the decay of the radioelements potassium, uranium and thorium from the top 40 – 60 cm of the soil, and can be used to indicate parent material mineralogy and weathering characteristics. It has been used at the airborne scale to infer soil properties such as textures, soil depths, % clay and parent material source (Wilford *et al.* 1997, Taylor 2002). Electromagnetics measures total ground conductivity and moisture content and, whilst it is not a salt map, it can be used as an indication of salt intensity and variation as well as textural contrasts in a profile (Henry, 2000). EM31 and EM38 were used as they cover relevant depths. The EM 31 penetrates to 6 m depth while EM38 only penetrates to 2 m depth.

## METHODOLOGY:

The study was split into three sections:

1. **Initial regolith /material mapping** – integration of the existing soils map with a landform map and 6 m drill hole data into a new interpretation of a regolith materials map to provide a basis for comparison. Drill hole analysis included textures, $EC_{1:5}$, pH on all samples, and XRD and XRF on selected surface samples and IC (ion chromatography, on soil solutions).
2. **The ground geophysical survey:** The Victorian Department of Primary Industries (Department of Natural Resources) provided a quad bike with a gamma-ray spectrometer (Exploranium GR320), EM31 and EM38 (Geonics EM- 31 MK2 and EM-38). Transects were undertaken at 20 m spacing with measurements taken every 1 second or approximately every 5 m.
3. **Processing and displaying:** The raw radiometrics and electromagnetic data were processed at Geoscience Australia. The datasets were then combined in a unsupervised classification in to a "fuzzy" boundary map for interpretation into soil properties. Correlations with the existing soil maps and regolith data were made.

## RESULTS & DISCUSSION

The radiometric response reflects the mineralogy and geochemistry of the parent material and weathered materials, including residual and transported clays, sand, minor gravel and gravel lags. This establishes a basis for soil identification through the recognition of one of the major soil forming factors defined by (Jenny 1941), parent material. The radiometrics image in Figure 2 indicates two hypotheses:

1. Two lithologies and the movement of the weathered fraction of each of these; or
2. One lithology and extreme variation in weathering across it.

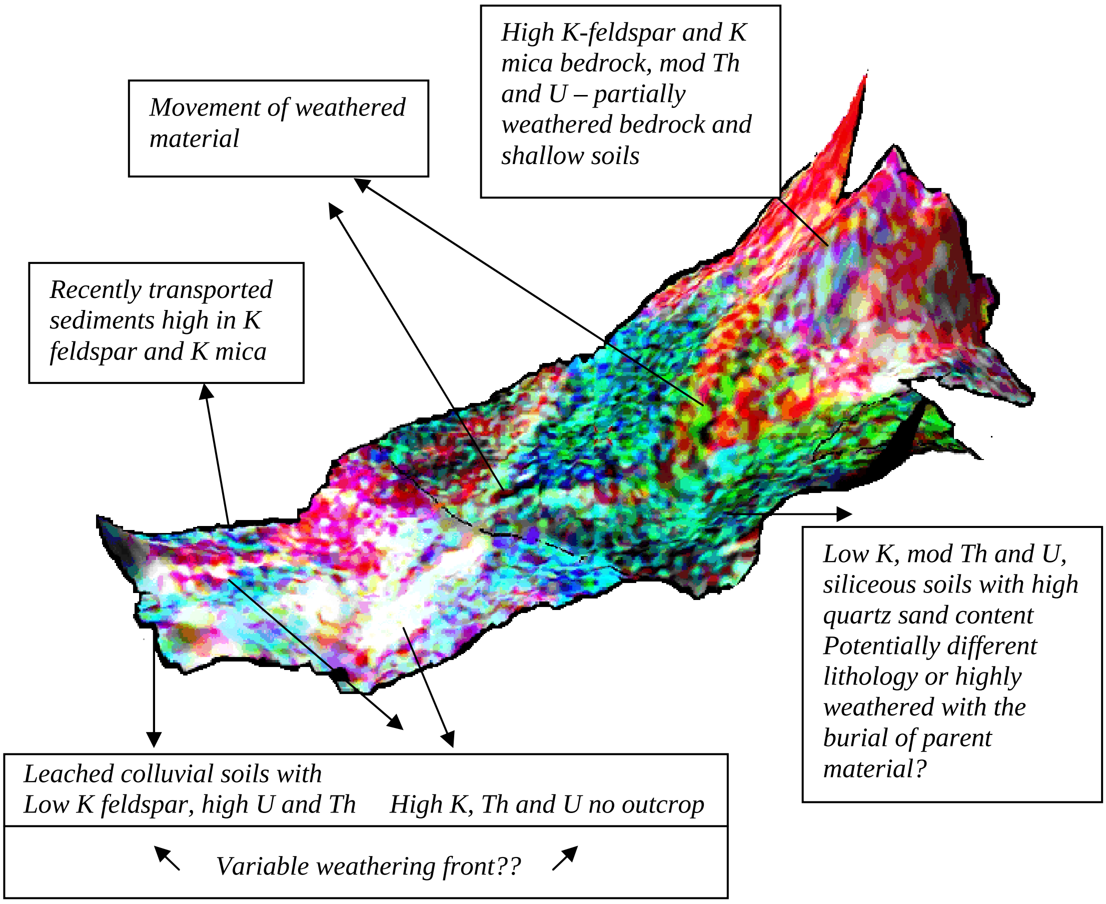



**Figure 2:** 3-Channel radiometrics draped over DEM and individual bands K, U and Th.

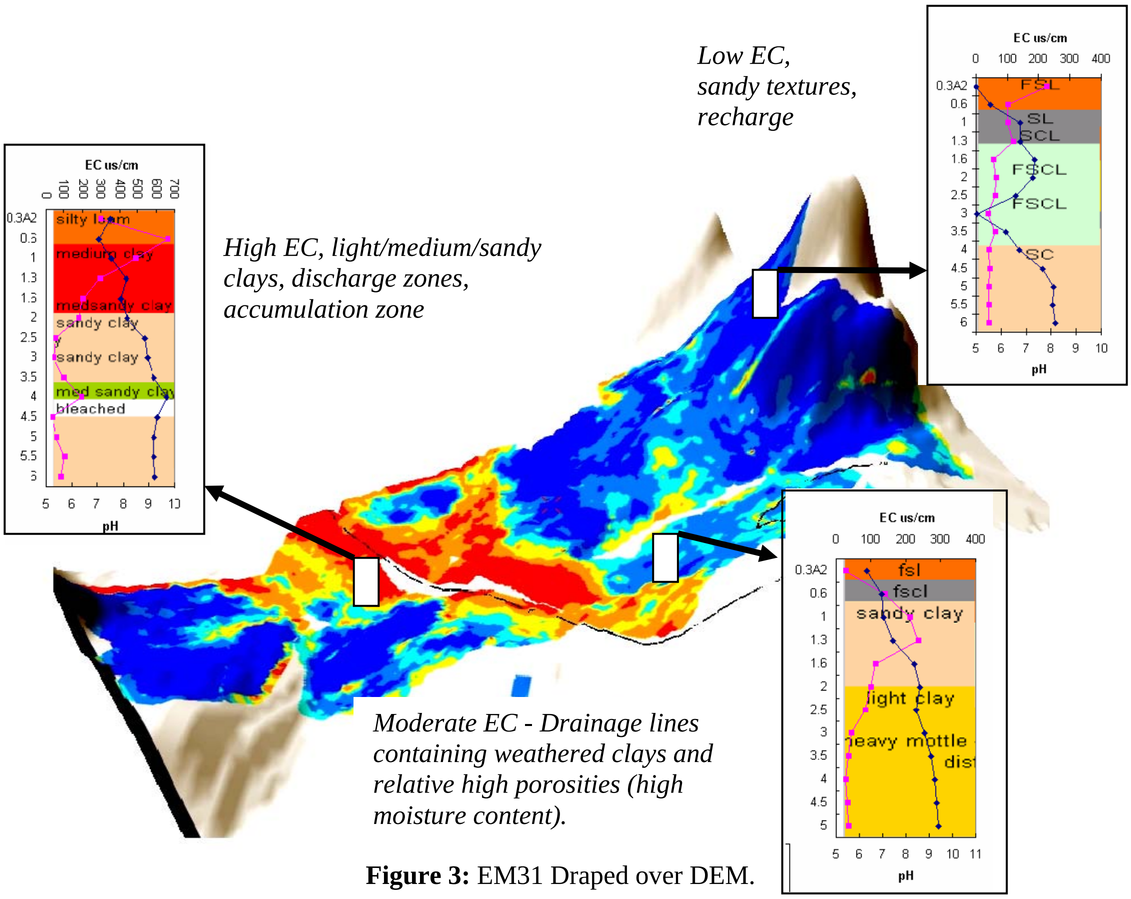
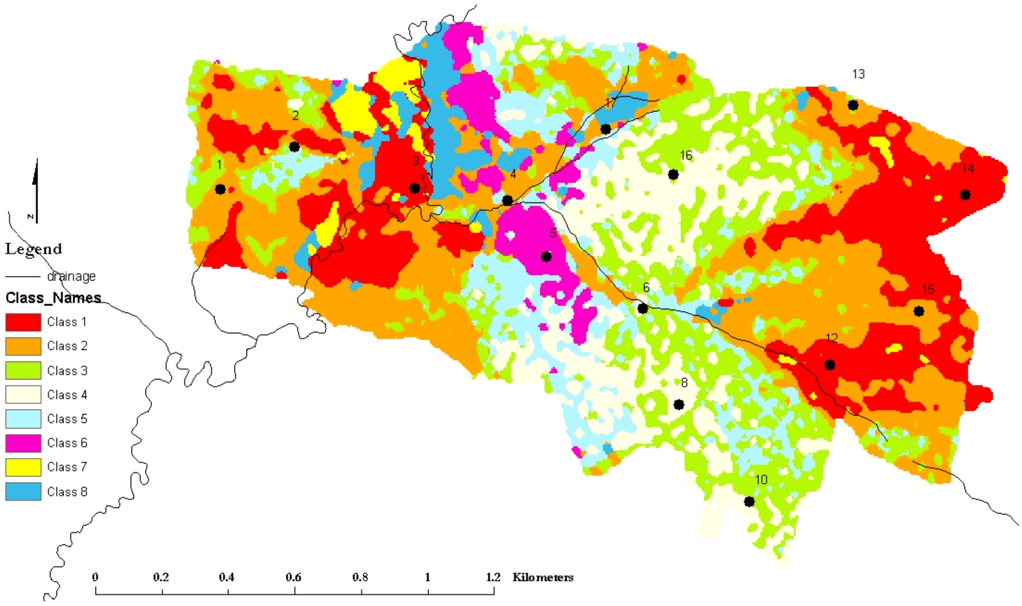



**Figure 3:** EM31 Draped over DEM.




*Class 1 : Shallow, saprolitic, sandy clay, low salts, low moisture, permeable, illite dominated?*
*Class 2 : Shallow sandy clays, low salts, permeable, illite dominated?*
*Class 3 : Sandy clays, low salts, illite/ kaolinite?*
*Class 4 : Sandy clays, kaolinite?* *Transitional zone*
*Class 5 : Sandy clays, mod salts* *Lower Nutrients?*
*Class 6 : Light/ sandy clay, high salts, erosion potential/visible, deep, increased H2O capacity*
*Class 7 : Medium clays, high salts, alluvial sediments, high nutrients, H2O capacity*
*Class 8 : Heavier textures, high salts, alluvial sediments, high nutrients, H2O capacity*

**Figure 4:** Unsupervised Classification of K and EM31.

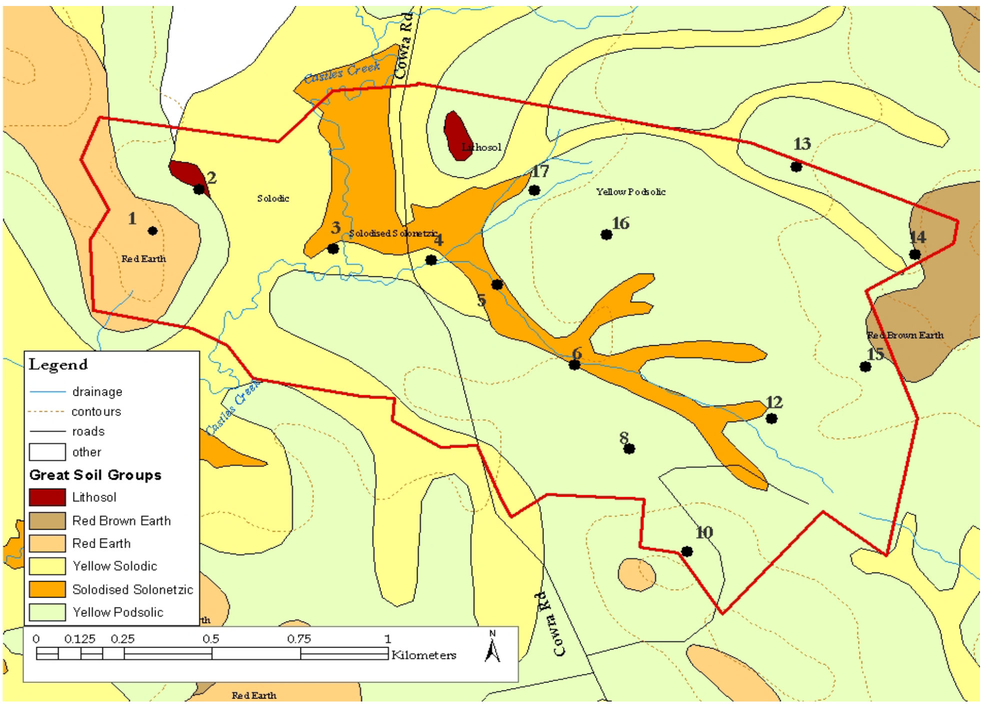



**Figure 5:** Detailed conventional Soil Map.

With interpretation and knowledge of mineralogical process we can make assumptions about textural differences across the landscape, the types of clay present and soil depths. This can lead to further assumptions about soil fertility and erodibility. Further validation by more field sampling and clay mineralogy could be used to test these hypotheses.

The electromagnetics adds further data with information on total anions and cations and soil moisture. This is an indication, again, of the weathering processes and of the original parent material and drainage characteristics, and could be seen as further validation of the texture contrasts and salt concentrations. The high values are co-located with zones of accumulation of the clays and are associated with breaks in slopes and watertable influences; the lows are co-located with high recharge areas and permeable textures (Figure 3).

The geophysical map reflects continuous high to low K and high to low EC readings. In combination with knowledge of their relationships to landscape processes, and in reference to detailed physical and chemical regolith data, it was found that there were good separations of areas of high clay, high salts that accumulate in the lower landscape, sandier textures and low EC's of the upperslopes, and the sandy textures and low EC's of the mid slopes (Figure 4).

The major advantage seen in this study are the "fuzzy" boundaries, which show gradual transitions across the landscape and the ability to spatially predict specific soil characteristics at any point. The difference in spatial detail and accuracy between the geophysical map and the traditional mapping methods can be seen in Figures 4 and 5. From a land managers perspective, this can result in a much more accurate view of the spatial extent of soil texture and nutrient variation. The more accurate the information, the more economically valid any management strategies can be, whether it is in the cost of fertilizer or earthworks, water management, or time and labor.

## CONCLUSIONS

Salinity management can be vastly improved. In terms of identifying salt stores and the potential paths of mobilisation and emergence, continuous accurate measurements of salt intensity, soil moisture and textural associations mean that EM profiling is far more advanced than the traditional soil map. Potential sites of degradation can be targeted pre-salt emergence and managed accordingly, e.g., fencing off, specific plants/crop planting, tree planting before symptoms appear. The radiometrics also add information on the potential sources and stores of salt by identifying minerals in parent materials that have particular clay weathering products more prone to cation exchange, and the level of weathering of the parent material, and therefore the zones of potential salt stores.

Further validation of the remotely sensed dataset is required. Due to the limitations in time and resources of an Honours year, only a brief overview could be gained on this method of regolith mapping. However, it illustrates new and exciting developments in the field of soil and regolith mapping that could hold the key to providing accurate efficient information to landholders, the lack of which has been one of the factors holding back widespread achievement of maximised, sustainable agricultural production.

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