THE APPLICATION AND ANALYSIS OF AIRBORNE GAMMA SPECTROMETRY (RADIOMETRICS) FOR MAPPING SOILS IN CENTRAL QUEENSLAND

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Abstract
The aim of the study was to determine the usefulness of airborne gamma spectrometry (radiometrics) data to map soils in the Bowen area in Central Queensland. The study involved developing a radiometric-lithology conceptual model and a pedogeomorphological–lithological conceptual model to predict soil properties in a trial area, determine the model success, refine, and then apply the improved model to another area. The models for the Greta Creek trial area used a 1:250000 geology map, radiometric data (thorium and potassium) and knowledge of pedogeomorphology-lithology relationships for the region. Soil properties were predicted for 106 sites in the Greta Creek trial area. Results of the Greta Creek study included the successful prediction of lithology (55.6%), the Australian Soil Classification order (65%) and soil profile class (29%). The models were refined and applied to 197 sites in the Bowen – west area. The refined model resulted in lithology successfully predicted at 63% of sites, Australian Soil Classification at 63% of sites and the soil profile class at 26% of sites. The incorrectly predicted sites were analysed. Overall, the radiometric data were useful in identifying soil characteristics to the level of Australian Soil Classification order and useful in delineating broad lithological units when used with a geology map.

Additional Keywords: soil, radiometrics, soil predictions, soil mapping.

Introduction
Soil data is vital for natural resource management. Issues such as land degradation, crop production and water quality are better understood with knowledge of catchment soil properties. Successful agricultural systems rely on a good understanding of soil resources and how they interact with crops and other components of our catchments such as water quality. Traditionally, soil data has been gathered from soil surveys or land resources surveys. These methods of gathering soil data rely on soil scientists augering or coring through the upper soil layers and describing soil attributes. The information gathered at each site is then interpreted together with landform and geological information to form soil boundaries. This technique of gathering soil data is cost effective for relatively small areas or site specific analysis but becomes expensive for large areas. Consequently there is a need to investigate alternative methods of gathering soil data that are timely, accurate and cost effective.

This study will trial the use of airborne gamma spectrometry (known as radiometrics) data to gather soil data over a relatively large area. Radiometric data includes potassium (P), thorium (T) and uranium (U). These three radioisotopes are naturally found in most rock types (Wilford *et al.*, 1997). When the rock weathers, the relative proportions of the P:T:U are reflected in the soils. Gregory and Horwood (1961) state that 90% of gamma rays are sourced from the top 30-45cm of the soil.

According to Wilford *et al.*, (1997), the amount and proportion of P,T and U which is emitted from the surface can be useful in mapping soil properties and regolith. Radiometric data is normally collected over large areas using an aircraft mounted scanner with the data collected digitally. The scanner measures the amount of P,T and U radiation emitted from the ground within certain parts of the electromagnetic spectrum.

The area selected for the study is the Greta creek to Bowen area in Central Queensland. The study area covers about 56,000ha and includes a wide range of geological units. The area has Holocene and Quaternary alluvium, tertiary sandstone, acid to basic intrusive and extrusive rocks and areas of metamorphism. The specific objectives of the study are to;

- assess potassium, thorium and uranium AGS bands in delineating lithology, geomorphology and soil properties,
- develop a conceptual model for predicting soil properties using geology, geomorphology and AGS data, and,
- using the conceptual models predict soil properties, soil profile classes, Australian Soil Classification orders and lithology in the 56,000ha study area and quantify the results.

Methods

The general approach to the study is to use the Bowen 1:250,000 geological map (Paine and Cameron, 1972), radiometric data and the soil – geomorphology relationships to predict lithology, the Australian Soil Classification order (Isbell, 1996) and soil profile class at specific sites in the landscape. The study methodology involves;

- developing a radiometric-lithology conceptual model and a pedogeomorphological – lithological conceptual model for the Greta creek trial area (approximately 6,000 ha),
- map landforms within the Greta creek area onto air photographs and select prediction sites,
- applying the lithology-soil model to predict soil properties at the prediction sites in the trial area,
- conduct a land resource survey to determine the accuracy of the predictions,
- the model will then be refined from the data collected from the trial area and applied to the much larger Bowen – west area,
- the models will be used to predict lithology, Australian Soil Classification order and soil profile class at sites in the Bowen - west area (approximately 49,000 ha),
- calculating the accuracy of the predictions and analyzing the inaccuracies.

Research on the relationship between lithology and radiometric data enabled the development of a conceptual radiometric-lithology model for the study. With some basic lithology – radiometric relationships, the Bowen 1:250,000 scale geology map and radiometric data (Potassium, Thorium and Uranium) were used to develop a preliminary conceptual radiometric-lithological model for the Bowen study. The radiometric data was acquired from the Queensland Department of Natural Resources and Mines and captured at 400m flight line spacings. The data were processed by the QDNRM, subsetted for the study area and classified into four classes for Potassium and four for Thorium.

An investigation into the soil, geomorphological and lithological relationships in surrounding soil studies (Hardy and James, 2000) enabled the development of a conceptual model for these three attributes. The radiometric-lithology model and the pedo-geomorphological-lithological model were then ready to be tested in the Greta creek trial area.

Prior to the application of the models, the landforms in the Greta creek trial area were mapped onto 1:25,000 black and white air photographs using a stereoscope. The prediction sites for the Greta creek area were positioned in the middle of landform units.

The conceptual radiometric – lithology relationship model was used to firstly predict lithology at each site then the pedogeomorphological-lithological relationships were used to predict the Australian Soil Classification (ASC) order and soil profile class. The soil profile class is used to group similar soil profiles based on similar morphology and chemistry. The predicted soil profile class code for each site was drawn onto the air photographs. Once the soil profile class for each site was predicted, a land resource survey of the Greta creek area was conducted.

The land resource survey involved visiting each site and using a hydraulic soil corer, intact 50mm soil cores were collected. The morphology and basic chemistry of each soil core were then described. Following the land resource survey, the predicted lithology, ASC order and soil profile class for each site were compared to those described in the field.

The accuracy of the Greta creek predictions were used to refine the lithological-radiometric model and the lithological – pedogeomorphological model. Once refined, these two new models were applied to the Bowen – west area. The sites were selected using the same methodology as for the Greta creek study. The lithology and soil predictions were also tested using a land resource survey. The predicted lithology, ASC order and soil profile class were then compared to those described at each site. The sites that were not predicted correctly were analysed to determine the reasons for the errors.

Results

Greta creek area

The prediction results at 106 sites in the Greta creek area were lithology 55.6%, ASC order 65% and soil profile class 29%. The reasons for the prediction errors are shown in table 1.

Table 1. Inaccuracies of predictions in Greta Creek area

	Reasons for incorrect lithology %	Reasons for incorrect ASC order %	Reasons for incorrect SPC %
Geology map inaccuracies	8	17	12
Complexities of alluvial fans	28	11	17
Subtle soil chemistry differences	-	8	29
Subtle differences in texture of topsoil	-	0	0
Topography / landform prediction errors	16	50	36
Difference in lithology	-	17	8
Due to radiometric model	51		
Total	100%	100%	100%

The Lithology was correctly identified at 57 sites. Most of the incorrectly predicted sites (51%) were due to the radiometric – lithological model. The inaccurate predictions were caused by the relatively broad radiometric classification classes which were not sensitive enough to detect subtle changes in lithology such as Dacite and Trachyte or Tonalite and granodiorite. The prediction of lithology on the footslopes was also difficult because of the variability in colluvium material and rock outcrops.

With only 57% of the sites correctly predicted for lithology, this had a negative impact on the ability to correctly predict the soil. However, some closely related lithology's such Dacite and Trachyte do produce similar soils, at least to the ASC order level.

The prediction of the ASC order was greater than lithology (69 sites). However, If we deduct geology map errors 6/36 (17%) and subtle subsoil differences 3/36 (8%), then the accuracy is 78/106 (74%). Half of the wrong ASC order predictions (19 sites) were caused by slight errors in predicting the landform, for example a pediment compared to a colluvial fan, or an undulating plain compared to a relict Tertiary flat.

The soil profile class was the most detailed level of soil classification used in the study. The use of the models returned a poor result for predicting this level of soil detail. However, if we take into account errors with the geology map (9 sites) and subtle subsoil differences such as pH and colour (22 sites) then our accuracy is 62% (66/106 sites) for predicting the soil profile classes and detailed soil profile information.

Bowen area
Once the model was refined and applied to the Bowen – west area the results of the predictions were lithology 63%, Australian Soil Class 63% and soil profile class was 26%. The inaccuracies and their reasons are shown in table 2.

Table 2. Inaccuracies of predictions in Bowen - west area

	Reasons for incorrect lithology %	Reasons for incorrect ASC order %	Reasons for incorrect SPC %
Geology map inaccuracies	36	22	21
Complexities of alluvial fans	16	5	21
Subtle soil chemistry differences		3	25
Subtle differences in texture of topsoil		19	10
Topography / landform prediction errors	14	41	23
Difference in lithology		15	3
Due to radiometric model	35		
Total	100%	100%	100%

The lithology was correctly identified at 124 of the 197 sites. The incorrect predictions were mostly due to inaccuracies in the geology map (36%) and the broad radiometric classes used in the radiometric-lithology model (35%). If we take into account geology map errors and complexities with fans 12/73 (16%), then the accuracy for predicting lithology is 163/197 (83%). The prediction of the fan lithology could be overcome using more radiometric classes.

The ASC order was correctly identified at 124 sites. Most of the inaccurately predicted ASC order were due to inaccuracies in predicting lithology, errors in the geology map and errors in predicting the correct landform for the pedo-geomorphological – lithological model. However, if we take into account geology map errors 16/73 (22%) and subtle subsoil differences 2/73 (3%), then the accuracy is 142/197 (72%).

The soil profile class (SPC's) was correctly identified at 52 of the 146 sites. With almost 40% of the sites incorrect for lithology, this made achieving a high percentage of correct soil profile classes difficult. Subtle differences in subsoil and topsoil accounted for 35% of incorrect predictions. Inaccuracies in the radiometric component of the conceptual model and its application to a landform accounted for 23%. If we take into account errors with the geology map (27 sites) and subtle subsoil differences such as pH and colour (32 sites) then our accuracy is (90/170) is 53%. Therefore, if the SPC's were conceptually broader, there would be a greater level of prediction.

Discussion

This study has tested the usefulness of radiometric data, 1:250,000 geology maps and local pedogeomorphological – lithological relationships to predict and map soil properties. In particular, the study has gauged the usefulness of relatively coarse geological data and radiometric data as components in predicting lithology, Australian Soil Class and soil profile class across a range of terrains and rock types.

The methodology chosen for the study has enabled the usefulness of radiometric data to be assessed for various levels of soil detail. The study has also identified some areas of traditional land resource surveying that contain sources of error. One of the problems associated with using the methodology included then reliance on broad geological units from the geology map together with broad classes of radiometric data to predict lithology. The study has demonstrated that the use of eight radiometric classes in such a diverse terrain and mix of lithologys was too coarse as an input data set to the radiometric – lithological model. Another source of error was the reliance on a stereoscope to predict the landform for the application of the pedogeomorphological – lithology model. In parts of the terrain, relative elevation may be a mere 5 m over many hundreds of metres and incorporate a range of lithology's. The incorrect identification of a hill rise compared to a mid slope landform caused prediction errors in undulating parts of the landscape. The use of 1m digital elevation models to identify landform in slightly undulating terrain would have maximised the prediction of Australian Soil Class and soil profile class in the study area by assisting with topography and drainage. General observations of the data derived from this study suggest that the Potassium data set is useful in delineating recent alluvial deposits and acid igneous rocks. Thorium was also useful in mapping areas of highly weathered colluvial, Tertiary deposits and basic igneous deposits.

Conclusions

This study has demonstrated that the use of 1:250,000 geology maps, with 400m radiometric data is useful in predicting lithology, especially broad lithological groups such as acid intrusive rocks and broad soil groups such as the Australian Soil Classification order. The coarseness of the input data sets make predicting soil profile classes or soil attributes such as subsoil pH difficult. However, if more radiometric classes were used, together with a 1m digital elevation model this would lead to a higher accuracy in predicting lithology, Australian soil classification order and soil profile class. The potassium and thorium data sets were useful in delineating differences in the age of alluvium and broad difference in lithology such as acid to basic igneous rock

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