A COMPARISON BETWEEN LABORATORIES FOR TOTAL AND AVAILABLE ESTIMATION OF THE METALS Cu, Pb, Zn AND U.

L.A. WHITE
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LAND CONSERVATION UNIT
CONSERVATION COMMISSION OF THE NORTHERN TERRITORY
P.O. BOX 38496
WINNELLIE N.T. 5789
# TABLE OF CONTENTS

1. INTRODUCTION ................................................................. 1  
2. METHODS ........................................................................... 2  
3. RESULTS AND DISCUSSION .................................................. 2  
4. CONCLUSION ..................................................................... 6  

APPENDICES

1. TABULATED AND GRAPHEd DATA ......................................... 9  
2. HORIZON DESCRIPTIONS FOR ROUND ROBIN SAMPLES .......... 29  

LIST OF TABLES

1. Chemical Results and Some Derived Statistical Data                   
   - Sample 1220 ..................................................................... 10  
2. Chemical Results and Some Derived Statistical Data                  
   - Sample 1400 .................................................................... 11  
3. Chemical Results and Some Derived Statistical Data                  
   - Sample 1421 .................................................................... 12  
4. Chemical Results and Some Derived Statistical Data                  
   - Sample 1865 .................................................................... 13  
5. Chemical Results and Some Derived Statistical Data                  
   - Sample 2031 .................................................................... 14  
6. Detection Limits Quoted for Assays Undertaken ............................ 15  
7. Chemical Results and Some Derived Statistical Data for Laboratory "H". 15  
8. Table recording the manner in which the laboratories presented their chemical results. 16  
9. Overall Sample Means after exclusion of "wild" data. 16
10. Occurrence of Significantly Different and "Wild" Data.

11. Incidence of Error Values expressed as a Percentage of Analyses Conducted.

12. Land Conservation Unit Soil Monitoring Data determined in 1980 by Laboratory B prior to the Round Robin.

13. Correlation and Regression Coefficients Arising from Comparison of 1980 LCU Data and Lab "B" Round Robin results.

LIST OF FIGURES

1. Laboratory mean Vs Sample mean TOTAL Cu 19
2. Laboratory mean Vs Sample mean TOTAL Pb 20
3. Laboratory mean Vs Sample mean TOTAL Zn 21
4. Laboratory mean Vs Sample mean TOTAL Mn 22
5. Laboratory mean Vs Sample mean TOTAL U 23
6. Laboratory mean Vs Sample mean AVAILABLE Cu 24
7. Laboratory mean Vs Sample mean AVAILABLE Pb 25
8. Laboratory mean Vs Sample mean AVAILABLE Zn 26
9. Laboratory mean Vs Sample mean AVAILABLE Mn 27

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SUMMARY

In order to obtain an estimate of the reliability of chemical assays of heavy metals in soils, several analytical laboratories were approached and requested to investigate a number of samples taken from the LCU soil monitoring library. In all seven laboratories, including four involved with Uranium Mining, agreed to take part in the study.

Five soil samples were distributed to the participants, in duplicate, in randomly coded containers, to be assayed in a prescribed manner for Total and EDTA Cu, Pb, Zn, Mn and Total U. Unfortunately the requested analyses were not fully undertaken in all cases, and two laboratories estimated total levels with alternative methods.

Results indicate a considerable degree of variation between laboratories, with some presenting what appear to be wild values.

Basic statistical analysis of results (employing regression and correlation coefficients) reveals that in general two laboratories produce high readings, while two tend to read low. The former laboratories also display a high incidence of data considered significantly different from the population.

The laboratory which had performed the initial work on the five samples in 1980 was found to give very good reproducibility with its Round Robin results.

Further work is required before heavy metal readings in soils can be satisfactorily compared from laboratory to laboratory.
1. INTRODUCTION

Concern is currently being expressed regarding the methods relating to, and the reproducibility of chemical information arising from all monitoring studies in the Uranium Province of the Northern Territory. Mining companies will shortly be required to undertake surveillance within their own project areas. It is necessary that results be directly comparable to baseline data already collected by the Land Conservation Unit (LCU).

An informal governmental meeting in June 1981 (chaired by Mr. John Paul - Transport and Works, Water Resources), involving Uranium company representatives and members of government regulatory bodies, agreed in principle to round robin procedures being initiated to clarify environmental monitoring techniques.

The aims of the soil monitoring round-robin were -

(i) to compare a number of laboratories each being given identical material and using identical chemical methods; and

(ii) to enable LCU a basis for its future surveillance responsibility in selecting check samples from company monitoring programs.

In all, seven laboratories took part, these were -

1. Amdel Pty Ltd . Adelaide SA
2. Analabs Pty Ltd . Perth WA
3. Denison Aust Pty Ltd . Sydney NSW
4. Pan Continental Pty Ltd . Jabiluka NT
5. Queensland Mines Pty Ltd . Naborlek NT
6. Ranger Mines Pty Ltd . Jabiru NT
7. Transport and Works . Darwin NT

The above list is in alphabetical order and bears no relationship to the coding used by the authors in this report.
2. METHODS

Five separate soil samples from the Alligator Rivers region were randomly selected from Land Conservation Unit's soil monitoring library.

These samples (horizon descriptions shown in Appendix 2) had been pulverized and subsequently split, and were forwarded, with a duplicate, to each participating laboratory in 8 dram plastic phials. All materials were coded by numbers 1-16, 17-32 etc. and randomly distributed to the companies. One set of 10 phials (involving 5 samples) has been retained by the Land Conservation Unit. In order to maintain confidentiality companies have been themselves coded as A-G. The code "H" is used to indicate the repeat analysis carried out by laboratory "F" on the material of company "E". This repeat analysis was by mutual agreement of the two companies and the authors had no prior knowledge of the arrangement.

Two analyses were requested of the laboratories:

(i) Total estimation of the elements Cu, Pb, Zn, Mn and U using a nitric/perchloric digest.

(ii) Estimation of available Cu, Pb, Zn, and Mn by an EDTA (ethyl-diaminetetra-acetate) extraction.

3. RESULTS AND DISCUSSION

A full listing of results from the participating laboratories is included in Tables 1-5. Several disparities which occur in the presentation of data should be noted.

All laboratories were requested to record to a detection limit of 1 ppm in the case of total levels, and 0.2 ppm for extractable levels. Some laboratories did not state detection limits employed, while some detailed their data with limits exceeding those required (Table 6).
Although participants quote total Cu, Pb, Zn and Mn, only five listed U levels, and only 4 have recorded available EDTA, thus limiting the comparisons that can be made.

Results coded "H" have been included in Table 7, but for interest only, as the authors had no control over the sub-sampling procedures that took place in the transfer of material from "E" to "F".

In the following discussion the authors have chosen to make two restrictions, as detailed below:

(i) results not actually specified, but given as "< 2" or "< 5" ppm, have been excluded because it is considered that a range is not valid for the statistical comparison used in this report, and recommendations regarding assignment of arbitrary values to results in this form are variable. The amount of data in the "less than" form is small (see Table 8) and its omission is not considered to markedly alter any conclusions drawn;

(ii) overall results exhibit considerable variability and in order to make some simplification for the purposes of this report "wild" data has been excluded. The basis of this exclusion being data ≥ 5 times the closest results from any other laboratory. Data taken out in this way is -

- sample 1400 Lab C Total Zn
- sample 2031 Lab A Available Zn
- sample 2031 Lab A Available Pb

Observing the above restrictions, the data has been depicted graphically (Figures 1-9) for each elemental analysis by plotting particular laboratory means for each of the five soils against the overall sample means (Table 9). This representation conveniently illustrates the extent of data dispersion and highlights those laboratories with readings considerably above or below the mean.
Total Cu and Pb analyses appear to be the most reproducible with only a limited scatter of results for each sample while, in contrast, the testing for total Zn leads to a much wider variation in results. Those samples with the lower total Mn values reveal only slight variation between laboratories, but for sample 1865 with an average Mn level of 550 ppm, the inter-laboratory differences are more pronounced. This tendency of readings of higher absolute levels being less reproducible is also revealed in graphs of total U and, to a lesser extent, the "available" data. Indications from the graphs show that the results of laboratories "F" and "G" may be considered the most consistent in that they rarely have readings at either the upper or lower limit of the range. Laboratories "A" and "E" on the other hand have a tendency to read "high" while "B" and "D" tend to read "low".

As well as being graphed, the data underwent basic statistical analysis (Tables 1-5) in order to isolate those results which differ significantly from the others in each chemical determination for each soil sample. For the purposes of this report the significantly different results are considered to be in error and are those lying outside the limits $\bar{X} \pm 2S$ (plus or minus two standard deviations from the population mean) and are included in Table 10. Regression and correlation coefficients between the duplicates for particular laboratories suggest that little of the variation could be attributed to poor splitting technique.

Laboratory "A" would appear to be alone in having difficulties in obtaining meaningful results for the available tests (particularly with respect to sample 2031), while laboratory "E" had some problems with total analyses. With the possible exception of 2031, no particular soil sample resulted in a high incidence of significantly different data. Combining these significantly different results with the extremely "wild" data (omitted from statistical analysis) a percentage error table has been drawn up (Table 11) which reveals that more than 10% of results from laboratories "A" and "E" are considered to be in error. Laboratories "B" and "F" gave rise to no "errors" although, of course, "F" has not been able to be evaluated for its analysis of total U and EDTA extractables.
Both laboratories "E" and "F" performed their analyses with methods differing from those requested and laboratory "E" produced results often considerably higher than the average readings. This is a somewhat surprising result, for the aqua regia digest (employed by "E") is generally regarded as being less rigorous than that of a nitric-perchloric digest. Subsequently, in the case of this round robin it may be suggested that the variation between laboratory "E" and other participants lies with technique, rather than the analysis method used.

When comparing the 1980 Land Conservation Unit (LCU) data (Table 12) for the five particular samples with those from the round robin, three points are worth noting:

(i) the analysis of this LCU material was originally undertaken by laboratory "B";

(ii) the 1980 and 1981 sub-samples, although selected from the same monitoring material, were split at different points in time;

(iii) the 1980 data only underwent one analytical determination (i.e. no repeats).

The 1980 readings tend to be lower than the overall average for the more recent work (a tendency of laboratory "B") , but only significantly so in two cases (sample 1400 EDTA Mn and sample 2031 EDTA Zn).

The reproducibility from 1980 to 1981 of the work of laboratory "B" is very good, as illustrated by Table 13 where correlation and regression coefficients approach 1.00. With rare exceptions, the variations which do occur fall within the detection limits quoted for the total assays (5 ppm), and it is possible that an upgrading of the detection limits to 1 ppm could further improve the correlation and regression findings. The variations between the two testing times for EDTA assays are generally less than 0.5 ppm.
In both cases of total and EDTA tests the results showing most dis-similarity are those of manganese. No satisfactory explanation of this behaviour could be found.

4. CONCLUSION

The round robin study has been able to achieve a comparison between a number of laboratories which perform soil analyses on material from the Alligator Rivers Region. The results, as forwarded by the companies, indicate a high degree of variability at the 5% level. The instance of "E" giving very high readings with a less rigorous method illustrates that laboratory technique can play a more significant role, than choice of method, in lab-to-lab variation.

On the basis of the lab-to-lab disparity revealed in this report it would not be possible at present to satisfactorily compare data presented by individual companies with the baseline and check data from LCU (performed by "B"). If company surveillance is to be carried out, the problems highlighted in this report will have to be rectified.
APPENDIX 1

TABULATED AND GRAPHED DATA

NOTATION REFERENCING USED IN FOLLOWING TABLES

- $r$ = Correlation Coefficient
- $b$ = Regression Coefficient
- $\ast$ = Wild Data, excluded from given sample set
- $\bar{x}$ = Given Sample mean
- $s$ = Standard Deviation of given sample set
- ( ) = Laboratory concerned.
- / = The oblique line on figures 1-9 represents those points where laboratory mean equals the sample mean.
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<td>6.03</td>
<td>12.82</td>
</tr>
<tr>
<td></td>
<td>6.44</td>
<td>5.45</td>
<td>11.14</td>
</tr>
<tr>
<td>G</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>12</td>
</tr>
<tr>
<td>( \bar{X} )</td>
<td>5</td>
<td>9.8</td>
<td>13.1</td>
</tr>
<tr>
<td>S</td>
<td>1.8</td>
<td>3.4</td>
<td>6.9</td>
</tr>
</tbody>
</table>
TABLE 6: Detection Limits Quoted for Assays Undertaken.

<table>
<thead>
<tr>
<th>Lab Code</th>
<th>TOTAL (ppm)</th>
<th>EDTA EXTR. (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu</td>
<td>Pb</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>F</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>H</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS  Unstated detection limits.
-  Test not carried out.

TABLE 7: Chemical Results and Some Derived Statistical Data for Laboratory "H".

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
<th>Mn</th>
<th>ANALYSIS (total)</th>
<th>COEFFICIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1220</td>
<td>27.09</td>
<td>12.07</td>
<td>9.11</td>
<td>30.54</td>
<td>1.00</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>27.64</td>
<td>12.31</td>
<td>9.05</td>
<td>31.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td>13.07</td>
<td>4.52</td>
<td>11.56</td>
<td>35.94</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>20.45</td>
<td>5.30</td>
<td>10.35</td>
<td>36.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1421</td>
<td>20.50</td>
<td>15.75</td>
<td>10.75</td>
<td>133.3</td>
<td>1.00</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td>20.25</td>
<td>16.00</td>
<td>9.25</td>
<td>136.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1865</td>
<td>15.50</td>
<td>14.00</td>
<td>26.00</td>
<td>320.0</td>
<td>1.00</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>17.42</td>
<td>14.39</td>
<td>27.52</td>
<td>328.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2031</td>
<td>6.53</td>
<td>6.53</td>
<td>11.06</td>
<td>22.11</td>
<td>1.00</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>6.44</td>
<td>5.94</td>
<td>10.89</td>
<td>21.53</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 8: Table recording the manner in which the laboratories presented their chemical results (i.e. in the "absolute" or "less than" form).

<table>
<thead>
<tr>
<th>Analysis</th>
<th>VALUE GIVEN (ppm)</th>
<th>&lt;2</th>
<th>&lt;5 absolute</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL:</td>
<td>Cu</td>
<td>1(A)</td>
<td>2(G)</td>
</tr>
<tr>
<td></td>
<td>Pb</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zn</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mn</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>EDTA:</td>
<td>Cu</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pb</td>
<td>5(A)</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Zn</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mn</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

* ( ) denotes laboratory concerned.

TABLE 9: Overall Sample Means after exclusion of "wild" data.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>TOTAL (ppm)</th>
<th>EDTA EXTR (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu  Pb  Zn  Mn  U</td>
<td>Cu  Pb  Zn  Mn</td>
</tr>
<tr>
<td>1220</td>
<td>24.5 15.9 12.9 33.6 7.7</td>
<td>1.6 1.7 0.8 2.5</td>
</tr>
<tr>
<td>1400</td>
<td>13.3 9.0 13.9 45.3 2.1</td>
<td>3.1 1.3 2.2 13.0</td>
</tr>
<tr>
<td>1421</td>
<td>19.3 21.3 21.1 140.9 5.1</td>
<td>4.6 7.4 2.1 125.9</td>
</tr>
<tr>
<td>1865</td>
<td>14.8 19.8 31.6 551.7 1.8</td>
<td>2.4 4.0 3.8 358.8</td>
</tr>
<tr>
<td>2031</td>
<td>5.0 9.8 13.1 22.4 1.9</td>
<td>1.5 0.6 1.1 8.7</td>
</tr>
</tbody>
</table>
### TABLE 10: Occurrence of Significantly Different and "Wild" ( ) Data.

<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>Element</th>
<th>1220</th>
<th>1400</th>
<th>1421</th>
<th>1865</th>
<th>3031</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL:</td>
<td>Cu</td>
<td>G</td>
<td>-</td>
<td>-</td>
<td>D</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Pb</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>E</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Zn</td>
<td>E</td>
<td>E(C)</td>
<td>C</td>
<td>-</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>Mn</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>E,E</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>C</td>
<td>C</td>
<td>-</td>
<td>E</td>
<td>-</td>
</tr>
<tr>
<td>EDTA:</td>
<td>Cu</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Pb</td>
<td>A</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>A(A)</td>
</tr>
<tr>
<td></td>
<td>Zn</td>
<td>-</td>
<td>A</td>
<td>A</td>
<td>-</td>
<td>(A,A)</td>
</tr>
<tr>
<td></td>
<td>Mn</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 11: Incidence of Error Values expressed as a percentage of analyses conducted.

<table>
<thead>
<tr>
<th>Lab Code</th>
<th>SAMPLE No.</th>
<th>1220</th>
<th>1400</th>
<th>1421</th>
<th>1865</th>
<th>2031</th>
<th>No. Anal</th>
<th>Error</th>
<th>Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>84</td>
<td>9</td>
<td>10.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td>90</td>
<td>4</td>
<td>4.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>90</td>
<td>4</td>
<td>1.1</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>1</td>
<td></td>
<td>4</td>
<td>1</td>
<td>50</td>
<td>7</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>1</td>
<td>3.3</td>
</tr>
</tbody>
</table>
TABLE 12: Land Conservation Unit Soil Monitoring Data determined in 1980 by Laboratory B prior to the Round Robin.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
<th>Mn</th>
<th>U</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1220</td>
<td>25</td>
<td>15</td>
<td>10</td>
<td>35</td>
<td>4.5</td>
<td>0.8</td>
<td>1.2</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>1400</td>
<td>15</td>
<td>5</td>
<td>10</td>
<td>40</td>
<td>1.1</td>
<td>2.7</td>
<td>1.2</td>
<td>1.5</td>
<td>6</td>
</tr>
<tr>
<td>1421</td>
<td>15</td>
<td>15</td>
<td>10</td>
<td>115</td>
<td>5.2</td>
<td>1.2</td>
<td>6.8</td>
<td>1.7</td>
<td>51</td>
</tr>
<tr>
<td>1865</td>
<td>15</td>
<td>10</td>
<td>35</td>
<td>415</td>
<td>2.2</td>
<td>0.6</td>
<td>2.7</td>
<td>1.6</td>
<td>320</td>
</tr>
<tr>
<td>2031</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>30</td>
<td>1.9</td>
<td>1.1</td>
<td>0.5</td>
<td>4</td>
<td>4.4</td>
</tr>
</tbody>
</table>

TABLE 13: Correlation and Regression Coefficients Arising from Comparison of LCU 1980 Data (Table 12) and Lab "B" Round Robin results.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
</tr>
<tr>
<td>1220</td>
<td>0.98</td>
</tr>
<tr>
<td>1400</td>
<td>0.96</td>
</tr>
<tr>
<td>1421</td>
<td>0.91</td>
</tr>
<tr>
<td>1865</td>
<td>0.99</td>
</tr>
<tr>
<td>2031</td>
<td>0.97</td>
</tr>
</tbody>
</table>
Fig. 1. Laboratory mean Vs Sample mean. - TOTAL Cu - ppm.
Fig. 2. Laboratory mean Vs Sample mean. - TOTAL Pb - ppm.
Fig. 3. Laboratory mean Vs Sample mean. - TOTAL Zn - ppm.
Fig. 4. Laboratory mean Vs Sample mean. - TOTAL Mn - ppm.
Fig. 5. Laboratory mean Vs Sample mean. TOTAL U - ppm.
Fig. 6. Laboratory mean Vs Sample mean. - AVAILABLE Cu - ppm.
Fig. 7. Laboratory mean Vs Sample mean. - AVAILABLE Pb - ppm.
Fig. 8. Laboratory mean Vs Sample mean. - AVAILABLE Zn - ppm
Fig. 9. Laboratory mean Vs Sample mean. - AVAILABLE Mn - ppm
APPENDIX 2

HORIZON DESCRIPTIONS FOR

ROUND ROBIN SAMPLES
APPENDIX 2

LCU Sample No 1220

District: Ranger Monitoring Site 27A
Location: Map Grid 27416 - 859587
Depth: 90-110 cm
Soil Description: Grey (2.5 YR 6/0), medium clay with coarse sand; massive structure, earthy fabric with moist slightly sticky consistence, prominent <20% <15mm diameter yellowish brown mottles.

LCU Sample No 1400

District: Ranger Monitoring Site 66
Location: Map Grid 27207 - 860107
Depth: 0-20 cm
Soil Description: Very dark greyish brown (10YR 3/2) organic loam with fine sand, massive structure earthy fabric, dry soft consistence, faint <2% <5 mm diameter yellow mottling. pH 5.5. (Field value).

LCU Sample No 1421

District: Ranger Monitoring Site 71
Location: Map Grid 26955-859970
Depth: 0-10 cm
Soil Description: Very dark grey (10YR 3/1) organic loam with massive structure, earthy fabric, moist firm consistence. pH 4.5. (Field value).
LCU Sample No 1865

District: Cooper Creek flood plain monitoring Site 13
Location: Map Grid 26955 - 866380
Depth: 0-5 cm
Soil Description: Dark greyish brown (10YR 4/2) medium heavy clay with coarse angular blocky structure, smooth ped fabric and dry extremely hard consistence. Root staining is evident. pH 5.0. (Field value).

LCU Sample No 2031

District: Magela Creek flood plain Monitoring Site 123
Location: Map Grid 27103 - 861333
Depth: 100-120 cm
Soil description: Grey (2.5Y 6/0) medium clay with sand, clay skins, faint 2% 2 mm diameter yellow mottles with faint 2% 2 mm diameter yellow brown mottles. pH 3.0. (Field value).
LAND CAPABILITY ASSESSMENT
FOR
DRYLAND ANNUAL CROPPING

A four-day symposium organized by
the Australian Soil and Land Resources Committee,
a technical committee of the Standing Committee on Soil Conservation
held at Toowoomba, Queensland,

PROCEEDINGS

Edited by K. J. Day and D. F. Howe

Published on behalf of the
Australian Soil and Land Resources Committee
by the
Conservation Commission of the Northern Territory
April, 1986.

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CONTENTS

Introduction 3

Summary of Recommendations 6

Opening Address

Theme 1 (Day 1) Information needs for land capability assessment for dryland annual cropping.

A. Assessing the productive potential of land for dryland annual cropping.
R. J. French, Department of Agriculture, S.A. 11

B. Assessing the potential for on-site off-site hazards associated with dryland annual cropping.
R. Junor, Soil Conservation Service, N.S.W. 25

Theme 2 (Day 2) Understanding the interactions between land and land use. (Field excursion, organised by R. Loch, Department of Primary Industries, Qld.) 36

Theme 3 (Day 3) Producing the desired land data in a cost effective manner. Dr J. A. Beattie, University of Tasmania. 37

Theme 4 (Day 3) Evaluating the information base.
B. E. Vandersee, Department of Primary Industries, Qld. 66

Theme 5 (Day 4) Effective methods of communicating the results of land capability assessment to various users.

A. The information provider's viewpoint.
D. F. Howe, Land Protection Service, Vic. 81
B. The information user's viewpoint.
Dr R. G. Woodward, Dept of Environment and Planning, N.S.W.

<table>
<thead>
<tr>
<th>Theme 6 (Day 4)</th>
<th>Achieving effective co-operation in the planning, conduct and application of soil and land surveys and of agronomic research. F. R. Gibbons, Land Protection Service, Vic.</th>
</tr>
</thead>
</table>

List of Participants
INTRODUCTION

Over the past 30 or so years, a vast range of information has been gathered at various scales concerning the nature of the landforms, soils and vegetation of many parts of the continent. Much of this information has been gathered at a reconnaissance scale (1:250,000) without any specific purpose in mind other than to provide such information where none previously existed.

More recently, land surveys have been increasingly directed towards the generation of an information base which can be evaluated for specific purposes. In general, such survey efforts have focussed upon areas where a potentially significant change in the type and intensity of land use has been foreshadowed. In such cases, survey effort has usually been concentrated both in spatial and functional terms, thus contrasting with the general purpose reconnaissance surveys mentioned above.

This shift towards more specific survey purposes highlights the need for better definition of information sought through surveys, and hence the scope, precision and accuracy of survey data necessary to provide this information. The effectiveness of existing methods of survey data collection and interpretation and possibilities of their improvement have to be examined.

The workshop proposal outlined on the following pages seeks to gather together people interested in the methodology, practice and extension of Land Capability Assessment for agricultural purposes. The broad aims of the workshop are:

• to examine the needs for land and soil survey information in relation to Land Capability Assessment for agricultural purposes;
• to highlight needs for research to improve the efficiency and effectiveness of agricultural Land Capability Assessment; and
• to suggest ways and means of initiating and facilitating such research.

Rather than frame the workshop too broadly, it is proposed to focus principally upon agricultural Land Capability Assessment in relation to dryland annual cropping.

Terminology

In the above context, the term Land Capability Assessment refers to the use of selected physical environmental criteria (such as effective rainfall, slope, soil depth, etc.) to assess the ability of the land to sustain a specified use without producing either undesired on-site or off-site effects.

It should thus be distinguished from Land Suitability Assessment, which, in addition to such physical environmental constraints, takes into account economic, social and political factors in evaluating the "best" use of a particular type of land.
The Terms: assessment, evaluation and appraisal are treated as being synonymous.

Broad Objectives of the Workshop

1. To briefly review the need for and limitations of Land Capability Assessment for Dryland Annual Cropping.

   Such a review will focus principally upon:

   - the need to predict the response of land to changes in land use, this response being measured in terms of
     - potential sustainable production
     - potential hazards (both on-site and off-site)

   - the closely associated need to identify the type and intensity of management inputs required on different types of land in order to
     - achieve and maintain an acceptable level of productivity
     - reduce hazards to an acceptable level.

   - the chief users of such information, e.g. regional planners; farmers; agricultural extension officers.

2. To identify the types of information which are required to carry out Land Capability Assessment for Dryland Annual Cropping.

   In particular:

   - information concerning the general requirements of various crops; and
   - information concerning the hazards associated with the production of such crops.

   The identification of these information needs will in turn highlight the specific types of physical environmental data which should be gathered during survey.

3. To examine various existing and potential methods of collecting, analysing and interpreting survey data for evaluation purposes.

4. To evaluate the range of methods of communicating the results of Land Capability Assessment to potential users of the information.

5. To examine the need for and possibilities of more effective cooperation between organisations involved in soil and land survey and agronomic research both at a State and Commonwealth level.
Each session of the Workshop commenced with a keynote address, followed by any questions of clarification. The speaker then proposed approximately five questions on the relevant theme for syndicate groups to discuss and propose answers. General discussion followed the presentation of each syndicate group's answers and a summing up provided by the keynote speaker.

Day 2 of the Workshop took the form of a field excursion to parts of the eastern Darling Downs to examine various aspects of dryland annual cropping in this region. Aspects covered at stops during the day included inherent attributes of the land including any hazards to the existing form of land use. Land use management variables and risks associated with climate were also presented by relevant extension officers from the Queensland Department of Primary Industries.

These proceedings are presented in the following order for each theme:

- keynote address;
- questions for syndicate discussion; and
- summary of the plenary reporting discussion.

Theme 6 is the only exception from this order where the keynote speaker presented a summing up of the conclusions reached at the Workshop and this is presented as draft recommendations from the Workshop to the Australian Soil and Land Resources Committee.
SUMMARY OF RECOMMENDATIONS

Recommendations from the Workshop to
The Australian Soil and Land Resources Committee for
Development of Specific Proposals to
Standing Committee on Soil Conservation

(a) Quantification of parameters used when assessing land capability/suitability should be addressed by increased research into

   (i) the relationship between soil erodibility, land degradation and crop productivity, and

   (ii) defining the limiting factors to the production of the chief crops in various regions of Australia and their relationship to performance from existing information on crop phenology and response.

   It is suggested that both research avenues could be the subject of proposals to the National Soil Conservation Program.

(b) Development of a minimum data set to be recorded when carrying out surveys for land capability assessment purposes.

(c) Increased emphasis be given to communications in relation to interpretation of land capability data.

(d) States be encouraged to actively pursue the adoption of the terminology of the Australian Soil and Land Survey Field Handbook with the view of developing a compatible data bank across States.

(e) Development of a national framework to show present progress in surveys and where needs are not being met.

(f) Identification nationally of specific training needs and/or directions for personnel involved in land capability assessment.
OPENING ADDRESS

B. J. Crack
Department of Primary Industries, Queensland.

Land resource appraisal is a prerequisite for the most efficient utilisation of the resource from the national level through to the individual landholder.

It has always been important. In Australia the early explorers and settlers made assessment of land capability. Some either with foresight, skill or good luck made sound decisions. Others were less successful and our history tells of much heartache as a result.

Certainly over the period of our land settlement, economic factors have been of major significance in determining success or failure but there have been many instances where incorrect land capability assessment and incorrect land management have been the root cause of subsequent difficulties. This has been true for both grazing and cropping enterprises and particularly true of irrigation development.

If the requirement for land capability assessment has always been with us the need today remains urgent and challenging. We have over a period acquired a lot of information on our land resources. We should be able to benefit from the experience of the past and use our current information to best advantage.

Particularly in the case of dryland cropping modern machinery and techniques bring an urgency to the requirement to identify hazards in land development and to define management requirements. We can make land development mistakes a lot quicker and in greater magnitude than previously.

On the other hand current technology does provide us with the opportunities to handle some of the constraints to successful land use and enables us to use cropping techniques more appropriately for sustainable production.

There is active continuing expansion of dryland agriculture in Australia and it expands more and more into lands of more marginal suitability. Expansion is occurring in areas with less favourable climate and onto soils which are more difficult to manage. These lands carry greater risks of economic failure and are generally more prone to land degradation hazards, both on-site and off-site. This carries with it the need to know what the land resource is, how it is likely to behave under the proposed land use and what type and intensity of management inputs will be required. This presents a substantial challenge to all people involved in contributing to sound land use planning such as ourselves. There is a real and urgent need to ensure, as far as is practicable, that expansion is directed onto lands where management practices can be specified which will result in sustainable economic yields and minimal degradation of the land resource. We need to be able to predict how the land will respond to changes.
There is an equally urgent need to have adequate resource inventories for lands already cropped so that assessments are available from which management guidelines can be defined to maximise production and reduce degradation to ensure long term viability of the resource.

In Queensland the rate of development of land for cultivated cropping is about 100,000 ha/annum and this rate of expansion is likely to continue for some time. However, much of this development is now occurring within western environments and on soils that are marginal for cropping. The environments are marginal in terms of low mean annual rainfall, low annual and seasonal reliability of rainfall and periods of high rainfall erosivity which cause severe erosion damage. Soils are marginal in terms of low plant available water capacity and nutrient status, poor surface structure, shallow soil depth and high soil erodibility. Low yielding crops in these marginal areas generally result in poor crop cover without adequate soil protection and smaller returns without providing for the means for investing in suitable management practices.

Of major concern in these areas, is that soil loss cannot be reduced to acceptable levels with traditional cropping rotations and soil conservation works. Improved cropping systems incorporating stubble mulching and minimum tillage practices in association with soil conservation structures are required.

It is therefore important to recognize those soils that are unsuitable for cropping in these environments, to provide management guidelines to overcome the limitations of the suitable soils and to research and develop management systems that will lead to long term productivity of the resource for future generations.

What sort of information is required? Information on soil type - soil properties is a basic prerequisite of any resource inventory. Soils are by and large classified on morphological criteria but for a long time pedologists and users of soils maps have queried the relevance of some classification criteria in determining land use capability.

We need to be able to interpret properties in the soils data base either directly or indirectly with regard to land use suitability or constraints.

Other resource data may not be in a form directly relevant to crop production or landscape stability and we may need to establish relationships between the resource data, productivity potential or degradation hazards and management needs.

Land capability classification schemes based on the American model of Klingebiel and Montgomery classed land on degrees of limitations. This was a useful scheme but was not crop specific. A greater need has been to develop suitability classifications appropriate to specific crops or crop groups rather than have a general scheme. This has focussed attention on the need for a better knowledge of the land attributes most significant for a particular purpose and how they may best be managed.
The need for more research very soon becomes evident; research aimed at understanding processes, research into interpretations and research into management practices.

In the past ten to fifteen years there has been an increasing demand for land resource data for specific purposes, much of it for areas of current or potential dryland cropping. This contrasts with a prior trend to collect a vast range of land resource data (on soils, landforms, vegetation) at the exploratory or reconnaissance scale without any specific land use purpose in its acquisition. With the increasing demand for land resources assessments where changes in the type and intensity of land use is planned or proceeding, and our limitations in funds and staff there is need to critically examine the effectiveness of our existing methods of data collection, its analysis and interpretation and how these can be improved. Computer processing of data allows us access to a far wider range of analyses and manipulations of the data for evaluation purposes than was available before and gives us the opportunity for more effective use of the data base.

We also need further research in order to take advantage of current technology as we need not only to identify relevant criteria but to quantify them. This continues to present a problem particularly in the area of soil physical properties where qualitative attributes prove difficult to define and quantify.

Modelling techniques provide us with the opportunity to mobilize the data we do have and to make predictions that do help overcome some of the deficiencies in data for specific areas. However, refinement of the models and their applicability in various circumstances is dependent on improvement of the data base.

This leads to a comment on the value of this workshop. Due in large part to the breadth of vision of our pedologists and enthusiasm for this cause we do have some soils data base. Of course improvements can be made but we have something to build on. We do have other data, e.g., climatological at a national level.

In the Australian scene where we have various Federal, State, University and other agencies working in the broad areas of land resource and land use research and management those involved need to make a special effort to ensure compatibility of data and of interpretations. We cannot afford the luxury of unnecessary overlap or discontinuities in the information and experience we build up. Furthermore, as research or changed technology enables us to improve our ability to handle particular problems, interpretations will change.

A sound data base will readily allow modification of interpretation to keep up with developing technology and will allow wider application of site specific research findings.

Land Capability information must be effectively communicated to the user. Users will extend from the technical level in planning and extension through to the landholder. Users are going to require not only classifications of capability or suitability but some
identification of the nature of land use limitations and of planning for management practices required to meet such limitations.

Because of the differing requirement of users and often because of the urgency for certain specific purpose information on land capability we have a great variety of approaches both to data acquisition and to reporting. The net result is an assortment of incompatible data and many deficiencies that limit later collation or integration on a broader base.

One of the reasons for the setting up of the Standing Committee on Soil Conservation was to facilitate the interchange of information between States and other agencies.

The Collaborative Study stressed the need for a national approach to land resource appraisal.

ASLRC has a broad responsibility to promote the development of more uniform and mutually compatible standards of soil and land resource survey practice - to encourage most efficient use of resources - to ensure greatest value to users.

We need more effective co-operation between organisations involved in soil and land assessment throughout Australia to allow more effective transfer of the information continually becoming available. The publication this year of the Australian Soil and Land Survey Field Handbook and forthcoming publication of the associated Methodology and Laboratory handbooks which are currently in preparation will give us valuable standards of terminology and methodology for the conduct of soil and land resource surveys. This will provide the basis for the development of more uniform approaches to assessment of lands for dryland cropping in the various States of Australia. This will be to our mutual benefit in managing our lands for sustained production and stability for the future.

A Workshop such as this is another very positive step in meeting some of these requirements, and in organising it ASLRC are fulfilling a priority task as seen by SCSC.
Theme 1. Information needs for land capability assessment for dryland annual cropping

Part A. Information needs for assessing potential productivity

R. J. French
Department of Agriculture, South Australia.

It is pleasing to see that a workshop is being held to evaluate the potential of land for a specific purpose. Too often in the past, we have believed that surveys of soil and land could provide this information. But most have been carried out without any specific purpose in view and have therefore not been as effective as one might believe, even though a large volume of data may have been accumulated in a file. In addition, the surveys have often been done after development and at a scale that is not adequate for farm evaluation. Land use decisions involve inputs from many people and it is the surveyor's responsibility to see that his data are available and can be interpreted by those involved in making the planning and economic decisions (Young, 1973).

Assessment of the productive potential of land begins, not with a knowledge of the soils, but with a knowledge of climatic factors and the capacity of plants to produce within these limitations (Pons, 1983). As well, the economic value of the crop should be considered along with the facts that both crop and agricultural practices are only partly soil-specific and rotations may be non-specific.

The main factors in the assessment of the potential production of an area are:

1. Climate

The basic driving forces are the amount and distribution throughout the year of day length, radiation, temperature, evaporation and rainfall. The monthly mean values for some of these factors for Katherine, Gunnedah and Kimba are given in Table 1. Thus, the climate of the months from April to September is similar for Gunnedah and Kimba, but markedly dissimilar for the remaining months due to the summer rain at Gunnedah.

Actual rainfall defines the variability of the growing season and this can be gauged from the decile values of rainfall (Table 2). The values of rainfall also indicate the period of high intensity rains, the probability of traffic problems for machines at sowing and harvest, and the probability of leaf diseases.

2. Crop Phenology

The phenology of a specific crop and its capacity to harmonise its development within the climate determines the potential yield. Key factors are temperature for germination, the date of the last frost
and the onset of stress temperatures, and the rainfall and evaporation in the growing season. Figure 1 shows the seasonal accumulation of temperature and evaporation for Kimba, and the weekly temperatures. Phenological data for some crops are given (Table 3) as well as the effect of time of sowing on reducing the intervals in crop development. The potential yield can be defined from this data using the formula of de Wit (1958) - Figure 2. There is a need for more phenological data on different types of crops.

3. Landscape Exclusion

The next step is to evaluate those factors in the landscape and soil that can limit the area to be cropped. This can be done by the Exclusion process (Austin et al 1977). Land with unfavourable physiographic features such as land that is too steep and too stony or subject to flooding or the development of salinity is excluded, as is land which is a long way from market. Much of the data for making the decisions on exclusion are available or easily obtained. Land can also be excluded from cropping because of its high socio-economic value, for example land that is needed for housing, recreation, water supply catchments or national parks.

4. Basic Soil Measurements

Land use not often coincides with soil boundaries. What is needed therefore from soil and land surveys is a data base of the soil volume and the relatively unchanging properties of soils, that can be interrogated to assess the likely growth of all types of plants. Key factors are:

(a) The unimpeded depth of the root zone; this indicates what crops and pastures can be grown in the soil, e.g. annual pastures need a root zone of 0.3m, wheat about 1m, coffee 1.0m. These factors can be observed from soil pits.

(b) The available water capacity in the root zone. This is usually determined by laboratory measurements at ~ 10 or ~33 kPa (1/10 ~ 1/3 atm) for the upper limit and ~ 1,500 kPa (15 atm) for the wilting point.

(c) The depth to a water table.

(d) Drainage; this can be assessed from the previous three factors.

It is important to measure available water content under field conditions of crop growth for these values are often lower than those derived in a laboratory. Over a range of soils in South Australia, the water use by crops from the 0-60cm soil layer was similar to the available water determined by 1/3 atm and 15 atm values in the laboratory. However, in the 60-120cm soil layer the water use by crops was never more than 30% of the laboratory determination (Table 4).
### TABLE 1. MONTHLY VALUES FOR CLIMATIC FACTORS AT THREE SITES IN AUSTRALIA

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A summary of some climatic factors for Kimba, South Australia (latitude ~ 33.09, longitude 136.25, elevation 264m)

a) Accumulated daily maximum air temperature and class A pan evaporation for two types of seasons, and average daylength (in hours).

b) Average daily maximum and minimum air temperature for weeks of the year.

The relation between maximum production of dry matter per mm of water use and the average daily pan evaporation from sowing to harvest recorded for different crops in the South Australian environment.
### TABLE 3. ACCUMULATED DAILY MAXIMUM AIR TEMPERATURES FROM SOWING TO FLOWERING AND MATURITY, AND THE ESTIMATED OPTIMUM TEMPERATURE FOR FLOWERING

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<th>Sowing to End</th>
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<td>1030</td>
<td>1800</td>
<td>2000</td>
<td>3000</td>
<td>23</td>
</tr>
<tr>
<td>Peas</td>
<td>1080</td>
<td>1600</td>
<td>2400</td>
<td>3300</td>
<td>20</td>
</tr>
<tr>
<td>Lupins</td>
<td>1100</td>
<td>1600</td>
<td>2400</td>
<td>3600</td>
<td>20</td>
</tr>
<tr>
<td>Safflower</td>
<td>1000</td>
<td>3200</td>
<td>3700</td>
<td>4700</td>
<td>28</td>
</tr>
<tr>
<td>Sunflower</td>
<td>1600</td>
<td>3100</td>
<td>2400</td>
<td>3100</td>
<td>28</td>
</tr>
<tr>
<td>Soybeans</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indeterminate</td>
<td>1600</td>
<td>2600</td>
<td>3900</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>Determinate</td>
<td>2100</td>
<td>3800</td>
<td>4200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Values vary ± 20°C depending on variety.

- Effect of Time of Sowing on Accumulated Temperatures from Sowing to Flowering

**Wheat**

\[ \text{Day} \times \text{Degree Max. Temp} = 2900 \times 5.0 \text{ (sowing day of year)} \]

**Lupins**

\[ \text{Day} \times \text{Degree Max. Temp} = 3100 \times 4.4 \text{ (sowing day of year)} \]
### TABLE 4. COMPARISON OF AVAILABLE WATER SUPPLY ESTABLISHED IN LABORATORY ANALYSES WITH AMOUNT OF WATER TAKEN UP BY WHEAT

<table>
<thead>
<tr>
<th>Site</th>
<th>Soil</th>
<th>Water Content at Depth</th>
<th>Water Content at Sowing</th>
<th>Rain Sowing to Harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(cm)</td>
<td>(mm)</td>
<td>(mm)</td>
</tr>
<tr>
<td>Wanbi-</td>
<td></td>
<td>56</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>Gnl</td>
<td></td>
<td>187</td>
<td>117</td>
<td>70</td>
</tr>
<tr>
<td>Taragoro-</td>
<td></td>
<td>82</td>
<td>46</td>
<td>36</td>
</tr>
<tr>
<td>Dy5</td>
<td></td>
<td>270</td>
<td>150</td>
<td>120</td>
</tr>
<tr>
<td>Minnipa-</td>
<td></td>
<td>134</td>
<td>79</td>
<td>55</td>
</tr>
<tr>
<td>Go1</td>
<td></td>
<td>297</td>
<td>178</td>
<td>119</td>
</tr>
<tr>
<td>Maitland-</td>
<td></td>
<td>232</td>
<td>144</td>
<td>88</td>
</tr>
<tr>
<td>Ge</td>
<td></td>
<td>494</td>
<td>308</td>
<td>186</td>
</tr>
<tr>
<td>Gladstone-</td>
<td></td>
<td>221</td>
<td>129</td>
<td>92</td>
</tr>
<tr>
<td>Dr2</td>
<td></td>
<td>464</td>
<td>279</td>
<td>185</td>
</tr>
<tr>
<td>Turretfield-</td>
<td></td>
<td>174</td>
<td>110</td>
<td>64</td>
</tr>
<tr>
<td>Dr2</td>
<td></td>
<td>347</td>
<td>203</td>
<td>144</td>
</tr>
<tr>
<td>Manoora-</td>
<td></td>
<td>340</td>
<td>187</td>
<td>153</td>
</tr>
<tr>
<td>Ug</td>
<td></td>
<td>800</td>
<td>446</td>
<td>354</td>
</tr>
<tr>
<td>Salter Spr.</td>
<td></td>
<td>350</td>
<td>197</td>
<td>153</td>
</tr>
<tr>
<td>Ug</td>
<td></td>
<td>720</td>
<td>405</td>
<td>315</td>
</tr>
</tbody>
</table>
A similar picture was obtained in cereal soils in the U.K. where the available water in the 50-120cm depth was only equal to the water content between -5 and -200 kPa (McKeague et al. 1984). Thus, a key requirement in determining potential production is to measure the changes in soil water content between sowing and harvest.

5. Other Soil Measurements

In the course of soil survey and soil research, many laboratory soil measurements are made such as texture, macro-porosity, structure, stability, bulk density, organic matter, saturation, hydraulic conductivity and chemical properties, including pH and nutrient status, but their individual effects on germination, infiltration, erosion and yield are not consistent.

While each property may have a dominant effect on yield in specific areas, the factors cannot readily be grouped to give a single index of productivity because:

(i) the values for each measurement are only relative values. They vary in space and during the growing season, and the soil properties are not all equally relevant in each environment. Thus Young (1973) has shown that the coefficients of variation for individual soil properties are rarely less than 20% and sometimes as high as 70%, and Webster and Butler (1976) found almost a negligible correlation between morphological and other soil properties of the topsoil.

(ii) the values cannot be extrapolated to other sites even in the same soil series. Their importance will vary with rainfall intensity and frequency, and the effect of management on soil cover. For example, areas with high intensity summer rains of 100mm in 2 hours on fallow would have different standards to those with winter rainfall during the period of crop growth. The limitation of the practical value of measurements of bulk density, mechanical impedance and air filled porosity in tillage trials has been emphasised by Osborne (1984).

Further examples of the limitation of soil-specific factors as criteria for productivity are as follows. Many years ago, Duley and Kelly (1939) showed that infiltration on one soil type varied with tillage practices, cropping systems and crop residues. These practices caused changes in porosity, bulk density and structure, but infiltration was more influenced by the surface conditions than by the soil properties.

Similarly, the yield of crops cannot be related to specific soil properties. Thus, in a survey of over 600 crops associated with the Ten Ton Wheat Club throughout the U.K., the soil type, as classified by topsoil texture alone, accounted for only 3% of the yield variance, and even when soils were grouped into soil series the variance increased to only 18% (Rothamsted Report 1983)
Even a specific measure such as organic matter is not a consistent index. Thus, Jenkinson (1965) showed that the yields of cereals grown on soils with 1.3% organic carbon in the top 30cm could equal those grown on soils with 2.1% organic carbon when 25 kg ha\(^{-1}\) N was applied. In another experiment where the application of dung had raised the soil nitrogen to 0.28%, highest yields of cereals were obtained with inorganic fertilizers on soils with only 0.11% N. Similarly, at Tarlee in South Australia on a hard-setting red-brown earth, the soil organic carbon has changed little from 0.93% and the nitrogen from 0.098% after eight years of either continuous cropping or ley farming (J. E. Schultz, pers. comm.), supporting the hypothesis of Grierson et al. (1972) that an optimum level of organic matter is set by soil texture above which little improvement in physical condition occurs. The affect of soil properties on yield is further complicated by the presence of root diseases and nematodes.

This uncertainty of appropriate soil criteria to evaluate potential production was discussed at two recent workshops, Cowra 1982, Toowoomba 1983 (Erosion Research Newsletter, January 1984). Concern was expressed at the lack of suitable techniques for measuring land degradation and the effects of soil loss on productivity. In fact, there was some evidence to suggest that yields were unaffected by removal of soil. A major problem here is that soil erosion is an intermittent process and occurs as a result of the interaction of site-specific factors such as rainfall intensity and distribution, and wind speed, particularly in relation to the amount of cover at the time, slope, soil type and cultivation. Thus, over 30 years at Wagga, four rainfall events out of 364 accounted for 48% of the total soil loss of 63.3 t ha\(^{-1}\) (Edwards, 1980). A similar relation was also obtained at Gunnedah.

While there are often requests for information on land use, there is usually not enough time to go out and make a separate soil or land survey. What is needed is a data bank which incorporates climatic data, crop phenology and the factors influencing root capacity and available water.

6. Assessment of Potential Productivity

Once the broad classification has been made, it is then necessary to evaluate the soil as a unit of production and to determine what technical inputs are needed to give high yields and erosion control. There are suggestions on how we should measure soil degradation and the effect of soil loss. However, more important than this is to measure the vulnerability of the soil that remains, and to find out how to restore it to full production. This approach sets the priorities for research as follows:

(a) determination of infiltration rate and amount of run off at those times of the year when the erosion hazard is greatest, e.g. during the period of high intensity rains, or when soil is bare in the rotation or when the crop is just emerging.
The measurements need to integrate the affects of rainfall intensity, surface cover, slope and length of slope, and soil properties on run off. They can be made by rainfall simulators with variable intensity control or with ring infiltrometers.

(b) determination of the wind erosion hazard at critical times during the year and during the rotation. This can be done by relating wind tunnel measurements to field surface conditions.

The hazards of water and wind erosion defined by these methods can be equated with the need for additional protection from supporting control measures, such as contour banks, stubble mulching, minimum tillage, application of gypsum.

(c) measurement of the crop yield per mm water use and relating this to potential yield. The relation tests the adequacy of current knowledge and serves as a basis for monitoring the effects of pH, nutrient supply and the disease control.

An example of the relation between yield of wheat and April-October rainfall (which approximates water use in South Australia) is given in Figure 3. After allowing for a loss of 110mm of rain by direct evaporation the potential production is 20kg ha⁻¹mm for the additional rain. Most crops yields are well below this value; the curved line shows the average district yield in S.A. The gain in yield from some treatments are shown by the lettered lines.

There is little value in attempting to correlate the effect of soil chemical and physical properties with yield when the yield is only a small percentage of the potential. Soil surveyors need to be involved in these multi-factor potential yield trials to evaluate the importance of soil properties in land use assessment.

7. Land Use Maps

The whole aim of any assessment of the production potential of land should be to provide information that is easily understood by local government planners, politicians and landholders. All make inputs into land use decisions but we tend to confuse the issue; for we use terms such as land capability, land use capability, land evaluation, land resource management and land suitability without providing specific or consistent inputs into each description or in their interpretation. Even at this workshop, specific definitions of land capability and land suitability were considered necessary in the program notes. There is confusion on the use of the term land use classes and in the scale required for survey and on the number of units of soil classification. Beckett and Bie (1978) note that surveyors tend to put a name to every variation of soil they encounter whereas extension officers relate to only 7 ± 2 soils in an area and farmers to only 3 ± 1 soils on their property.

Furthermore, land use maps are not immutable products and they can become inadequate with changes in farm size, when new and different crops are introduced, when soil acidity develops, or when new technology such as reduced tillage is adopted.
FIGURE 3. The relation between grain yield of wheat and April - October rainfall for selected experimental sites and farmers' paddocks in S.A. The sloping line indicates the potential yield relation. The curved line (---) shows the district yields in S.A. These are only about 1/2 the potential at 250mm and 1/3 the potential at 400mm. The responses to different treatments are shown by lettered lines linking points. Yield increases were obtained by the application of nitrogen (points linked by a B line), phosphorus (C line), copper (D line), control of eelworms (F line) and multi-factor research (J line). Yield reductions occurred because of delayed time of sowing (A line), effects of weeds (E line) and waterlogging (G line). Variation in yields in districts are shown by the H lines. (After French and Schultz Aust. J. Agric. Res. 35 (in press))
While a re-sorting of the data in existing soil surveys will give some answers to the questions posed above, the need for better descriptions from which planning decisions can be made will only come from a computer data base of climatic and crop factors and a minimum set of soil values defining root depth and available water. This data base is far more important than classifying soils according to a new system.

This data base should allow us to predict the outcome of a range of possible land use policies and predict the strategies that are needed to manage new crops or new management practices.

Our aim therefore should be to produce maps which present "Options for Land Use" to the planners and users. This requires:

(i) the production of maps with yield potentials of crops, based on climatic factors and crop phenology;
(ii) a procedure for excluding land with unsuitable physiographic features;
(iii) data base with a minimum data set which can identify the depth of root zone, the available water capacity and the depth to a water table in the different soils.

These criteria are similar to those recommended at a European Community seminar on soil survey and land evaluation at Wageningen, Netherlands in September, 1983. Once the land use has been determined then specific research projects are needed to assess the erosion hazard and the technical inputs to reach the productive potential.

A soil and land resource survey is not an end in itself; other disciplines and organisations make contributions to land use decisions. In spite of some promising trends in integrating soil survey data with other disciplines, progress so far is not adequate for either the planners or the landholders who carry out the land use.
References


Theme IA - Questions Posed and Responses from Working Groups

1. How important is a climatic data bank in deciding land use?

It is most necessary to have such a data bank to relate to crop phenology and potential crop yield. Some thought it would be best served by obtaining the data from the CSIRO, Division of Water and Land Resources (H. Nix) - others believed that some measurements on farms should be made to supplement the CSIRO data bank. There may be a need for additional data on rainfall intensity and data from arid lands.

2. How important is it to be able to assess rooting depth of the profile and the available water content?

This was considered very important and while some information could be interpreted from past surveys, it is essential that specific assessment be made in all future surveys. There is a need to adopt a uniform approach to this methodology and to correlate measured values with observable features in the soil.

3. Is there a need for integrated research to define the erosion hazard at critical times during the year?

This research should link factors that influence soil loss, and loss of production. A methodology is required to give some quantitative estimates of erosion hazard from routine survey practices.

4. Is there a need for potential yield experiments?

It was generally agreed that there is. Some groups thought the work should be done by agronomists, others that soil surveyors should be involved in multi-disciplinary work to understand the relative importance of soil characters and to assist in interpreting data for planners. Minimum data recording standards should be related to the detail of the planned research.

5. How should the data be collected and presented to users?

There was general agreement that there should be a data base which could be interrogated for a range of purposes, including changes in land use. The data base should include a minimum set of data relating to soil properties and there should be no confusion in the use of terminology.

There was disagreement on how much the surveyor should be involved.

One group thought it more important that the extension officer should be involved throughout the survey; others thought it highly important for surveyors to sell their skills and expertise and present information in a form readily understood by planners.
Theme 1. Information needs for land capability assessment for dryland annual cropping

Part B. Assessing potential hazards

R. Junor
Soil Conservation Service, N.S.W.

This is a particularly relevant topic to the Soil Conservation Service of New South Wales as the Service is nearing completion of a programme of land capability mapping of the Eastern and Central Divisions of New South Wales. Covering an area of approximately 38 million hectares and mapped at a scale of 1:100,000, the programme has highlighted many of the problems to be discussed at this Workshop.

Interestingly enough, it is within the dryland annual cropping areas that the majority of the land capability problems arise. One of the principals in the programme — and who is here at this Workshop, Graeme Short from Inverell — has been extensively involved in sorting out these problems. He will be able to raise more specific aspects of the problems than I can cover in this review.

Before I proceed to develop this theme, I would ask you all to pause a moment, stand back from your work and ask the following questions that are fundamental to any worthwhile planning activity.

Q1. Who is going to use my maps?
   i.e. Identify your client(s).

Q2. For what purpose are the maps to be prepared?
   i.e. Identify your objective(s).

Q3. Am I collecting the relevant information and presenting it in a form that can be acted upon by the user?
   i.e. Identify the product(s) and its level of acceptance.

I consider that without identifying these three elements at the commencement of the planning activity then you are wasting your time and effort and your personal credibility will suffer.

This period of sorting out the issues prior to undertaking land capability assessment will assist in avoiding many of the potential hazards that are associated with the collection and input of data, its interpretation in the mapping process and how the information is to be used.

The first problem has been one of definition — what do we mean by cropping land? This is not as silly as it may seem. In the Darling Downs it is obvious. But what happens when there are limitations of soils or climate such that crops cannot be grown continuously?
For example, if land can be cropped once every five years, is it cropping land? What about if land can be cultivated once every alternate year, such that there is a ley phase after each crop? And what about land that may be consecutively cultivated for two or three years and then left under pasture for five or six years? Are these cropping lands, or are they grazing land which are occasionally cultivated? The problem is not only academic; it is a practical problem.

If the Service states that any land which carries a crop, irrespective of the frequency of the crop, is cropping land, then we would be preparing maps that show cropping well into the Western Division of New South Wales. And if we say it is cropping land, then the politicians, the planners and the farmers may take the map at face value and suggest that it can be continuously cropped, irrespective of the limitations of the land. We run the risk of giving endorsement to cropping in semi-arid lands without clearly setting out the constraints caused by the physical site limitations and land management requirements which if ignored will foster land instability.

Thus, we need to define precisely what we mean by cropping land. The Service has accepted the current definition (see attached notes) and expanded its definitions of "grazing" land to incorporate the feasibility of planting an occasional crop. It was a case of rewording the definitions to enable the existing classification to be used. We did not want to get into the situation of having to establish a new classification.

One thing to note - the word used is cultivation or tillage and it is defined as shattering or inversion of the soil. Thus it does not include cropping systems using minimum or zero tillage methods for planting of the seed. These systems are considered to be outside the criteria of the land capability classification used by the Service. Growing a crop under zero till methods is equivalent in the effect upon the soil, as growing a pasture.

There are two principal aspects associated with the determination of land capability assessments which present potential hazards for the planner. In general there is a lack of basic resource data and secondly there is the lack of criteria concerning the growing requirements of current and potential crops.

**Dealing with the first aspect: the lack of basic resource data.** Most land capability and land suitability classifications consider the following criteria: climate, landform, soils, geology, soil and site drainage characteristics, soil erosion hazard, physical limitations (e.g. rock content), chemical deficiencies or toxic concentrations, vegetation characteristics, existing land use. For the 1:100,000 land capability mapping programme in New South Wales, the majority of this information is not available at anything approximating a reliable scale.

Within the 1:100,000 land capability mapping, those doing the mapping have to integrate all these data from the aerial photographs and from local knowledge to derive the land capability class. There is no time to prepare maps of the individual attributes. It is simply a synthesis of all these criteria by the mapper in his mind and then determining and drawing the land capability unit and giving it a class.
For some of the characteristics ~ landform, site drainage, soil erosion, vegetation characteristics, existing land use ~ these are easily interpreted by any person experienced in aerial photograph interpretation techniques. Geology is reasonably well covered in New South Wales by published maps. More difficult, and in some cases impossible, is the interpretation of climate, soils, soil drainage characteristics and chemical deficiencies or toxic concentrations.

Soils data are particularly limiting. There are not any maps of soils covering the entire Eastern and Central Divisions of New South Wales that are reliable to the scale of interpretation for the land capability mapping. This means we are dependent upon very general maps or local knowledge. If there is neither then we really are in trouble! This seems to be a common problem in other States as well.

The Service has recently commenced a Soil Landscape Mapping Programme for the Eastern and Central Divisions of the State at a scale of 1:250,000. Whilst the undertaking of the Programme is out of phase with the State Land Capability Mapping Programme, it will provide a more detailed State-wide resource inventory than the existing 1:1,000,000 Atlas of Australian Soils. This programme will complement to some extent the Land Capability Mapping Programme; provide resource information for the preparation of Regional Environmental Plans; allow a more appropriate basis for decisions on the use and protection of the better soils of the State for agriculture; and for the Soil Conservation Service, provide a basis to target State expenditure for the control of soil erosion.

Characteristics of the soil required for land capability classification are:

* depth
* texture
* structure
* soil drainage characteristics
* soil deficiencies or toxic concentrations
* physical limitations
* soil erodibility
* soil moisture holding capacity

Each is important in trying to determine land use types appropriate to each parcel of land.

The second aspect is the lack of criteria concerning the growing requirements of crops.

This was typified recently with land capability mapping in the northern part of New South Wales in the triangle Moree ~ Collarembri ~ Mungindi. It is an area into which cropping has only recently extended and could be considered as a marginal area.

The first criterion is the climate ~ is the growing season long enough to produce a crop? In this area, the critical feature would be rainfall. The total amount, when it falls, its reliability. Thus rainfall records need close examination. It is not the average or median rainfall that is used to determine the capability of the area for
growing crops on a regular basis. The figure we have been using is the third quartile. The Service considers that if the third quartile rainfall exceeds a specific amount, then the area is suitable for crop production - other factors being satisfactory.

Inter-linked with the climate are the soils' characteristics. The heavy clay soils are suitable for cropping. They are low sloping (1/2% gradient) to flat, with good water holding capacity. Given the pattern of rainfall, they will be able to store sufficient moisture to carry the crop through to maturity. At the other end of the scale are the very sandy soils often associated with prior streams. The lack of structure, the low water holding capability and their likelihood of blowing under prolonged dry conditions when cultivated indicate that they are unsuitable as cropping lands (in the coastal parts of New South Wales, these characteristics may not be limitations because of the higher and more regular rainfall). These two groups are easy to classify.

However, it is the in-between soil types - those with increasing proportions of clay that are difficult to classify.

At what proportion of clay in the soil, and under what climatic conditions, is the soil considered to be suitable cropping soil, i.e., subject to inversion or shattering actions during the preparation of the seedbed.

If there is insufficient clay, water holding capacity will be low and the soil will be subject to wind erosion during periods of fallow. What would constitute a reasonable level of clay in the soil so that these potential problems are not limiting to land? The Service cannot answer these questions - they require further study. These requirements need to be identified now so that future soil surveys can provide this information.

If we accept that the different soil types have different land capabilities (in the north west the alternatives may be Classes I, II, IV, VI or VIII) then it brings up the point I made earlier about the lack of resource maps. It can be difficult to identify many of the different soil types from aerial photographs and there are no maps available.

In the Moree - Collarenebri - Mungindi area, the Service has been relatively successful in using aerial photographs to map some of the soils. The heavy clays are easy to identify, as are the elevated prior streams. However, those prior streams which are not elevated above surrounding terrain and all the other areas of lighter-textured soils have been difficult to identify, particularly if they are under pasture or a mature crop.

In this area of the State, Landsat imagery, utilising ratioing techniques may be extremely useful to identify and to map the different soil types, and hence the different capability classes. Although the photographic images of Landsat show extremely clear patterns of major soils types in the Namoi Valley of New South Wales, there have not been any detailed studies to investigate their full potential for mapping soils in this region.
Erosion hazards are reasonably easy to predict, as there has been a fair amount of research and empirical observations within Australia.

Less easy to predict is the effect of different land uses on soil degradation, embracing soil erodibility, but including other factors (structure, drainage) as well. This needs more research, and relatively quickly as production techniques are changing quite rapidly in New South Wales.

Management effects can produce a potential assessment hazard. Many examples can be produced of farms particularly in low rainfall semi-arid lands where the owners have been successfully growing crops for three generations without any apparent adverse effects to the land, yet their neighbours can destroy soil fertility and cause significant land degradation to their properties over a ten year period. Management skill, timeliness of operation are essential to maintain a sustainable farming operation in these lands. The problem that arises is how do you give recognition to the high level of management skill which is required to farm this land in the land capability assessment. Management needs in these areas should be a requirement which is included in the land capability assessment.

Catchment effects in relation to land capability assessments need to be considered. Land capability is very often related to the on-site effects of land use on a parcel of land. Although David Howe's preamble list states the need to consider off-site, as well as on-site effects in land capability, this is rarely done. Mappers often assume that if there are no deleterious on-site effects, then off-site effects will also be minimal. In the last few years we have seen this is not so, by witness of the rise in salinity in the groundwaters under a significant proportion of our agricultural and pastoral land.

In making recommendations in terms of land use potential, we may also have to make recommendations as to land use practices. In areas of high salinity hazard, it may be necessary to specify minimum timber retention levels, and the patterns in which they are to be retained. In areas where soil degradation (in any one of its manifestations) is likely to occur, what land management practices are required with each feasible land use alternative to maintain it at or close to its original state?

**Time Scales for Manifestation of Effects**

This is a difficult point to discuss and one dependent upon your own training on values. If you are an economist you work on one set of values - if an industrialist, another and if an environmentalist, something completely different.

My view - there should be no fixed time scale, but one that is open ended. It is impossible to predict long term effects in many cases.

Problems of salinity which are occurring only now may have started 50-60-80 years ago. Others may be very much more rapid and caused by an unusually severe but extremely rare storm event. As the caretakers of the nation's agricultural lands we should be always on the lookout for land and soil problems and take remedial action once they commence.
Land use effects should not be considered only in terms of our lifetime, but in terms of succeeding generations as well.

Data and information needed to predict hazards:

Some have been discussed in detail in preceding pages:

- climate
- soil types and characteristics
- landform (slope, terrain type and shape)
- geology
- site and soil drainage
- soil erosion hazard
- physical and chemical limitations
- vegetation
- existing land use

Note that some of these features will not necessarily cause a hazard, but could be termed a constraint. It may be appropriate therefore to retitle the paper:

Information Needs for Assessing Potential Hazards and Constraints.

General Comment

Most organisations undertaking various types of land assessment have developed methods and expertise that are usually appropriate to the task. Individual preferences are very hard to change, likewise preferences of individual departments are difficult to change. It would be preferable to work out a system that takes existing survey information from the individual States and develop some type of national assessment.

Secondly, the value of general purpose surveys should not be overlooked. They provide information where there is none, and in New South Wales, that is important. Most mapping organisations should be looking to the production of general, as well as specific information and maps.

Mapping and reporting the information are the easiest phases of a project. The most difficult stage is to get a planning authority to make use of the information to its maximum level. This point is addressed in later topics, but it would be worth emphasising from the start that unless the information is used properly, then there is no point in collecting it at all.
APPENDIX

SOIL CONSERVATION SERVICE OF NEW SOUTH WALES
LAND CAPABILITY CLASSIFICATION

Land Suitable for Regular Cultivation (Classes I, II and III)

Soil must be capable of sustaining at least two successive seasonal or annual tillage phases for crop production, in which the tilled layer is inverted or shattered without producing either a significant increase in soil erosion susceptibility or a significant deterioration in soil structure.

The proportion of time under tillage and crop shall not be less than one-half the length of time under other land uses.

Class I

Land of low soil erosion hazard, subject to water erosion only during flood events and wind erosion during prolonged droughts. Special soil conservation works or practices are not necessary except those management factors necessary to preserve soil structure or productivity.

Class II

Land of moderate soil erosion hazard, subject to sheet, rill, gully and wind erosion where the erosion can be controlled by cultural techniques such as strip cropping, conservation tillage, adequate crop rotation, and the retention of windbreaks in areas subject to wind erosion.

Land in this class is generally subject to sheet, rill and wind erosion, although in some cases it may be affected by gully erosion where the gullies have been formed by run-off across the slope from adjacent terrain units. Although soil loss by sheet, rill and wind erosion may equal or exceed soil lost by gully erosion, its impact upon the ground surface is less obvious. Soil erosion can be controlled by land management practices generally included under the term cultural practices, e.g. strip cropping, conservation tillage (stubble retention, tine rather than disc or mouldboard cultivations, minimum tillage, direct drill) and by adequate crop rotation, specifically with a pasture phase. In the western limits of the cultivated lands, some form of timber retention to serve as windbreaks is recommended to reduce the wind erosion hazard.

Class III

Land of moderate to high soil erosion hazard, subject to sheet, rill and gully erosion where the soil erosion can be controlled by the use of structural soil conservation measures, or by very strict land management practices where tillage of soil is avoided during periods of high soil erosion hazard. In the latter circumstance, this will involve manipulating the cropping or rotation phases to avoid times of high soil erosion hazard.
In most parts of New South Wales, land in Class III will require a rotation phase to maintain soil structure and productivity, reduce disease and weed infestations and decrease the erosion hazard.

Land Suitable for Grazing with or without Occasional Cultivation (Classes IV and V)

Land well suited to grazing over the long term. Generally comprises two major land types:

a. Land suitable for cultivation on an irregular basis owing to the severe soil erosion problems likely to develop if cultivated continuously. Land included in these classes cannot produce two consecutive annual crops without a significant breakdown in soil structure under the conditions specified for cultivation, but may be cultivated for one crop without a breakdown in soil structure, followed by a period under pasture. Crops may include grain, fodder or forage species.

b. Land not suitable for cultivation for annual crops owing to climate, physical or chemical limitations of the site. However, the land is suitable for cultivation for the establishment of a permanent pasture. Physical limitations may include such soil characteristics as shallowness, heavy texture, lack of structure or weakly structured, low water holding capacity, high erodibility and impeded drainage and site characteristics such as slope gradient, periodic inundation, seepage flows, and exposure to climatic extremes (frosts, cold air drainage, hail). Chemical limitations mainly comprise toxic nutrient levels (including excess salinity) but may also comprise soils which exhibit nutrient fixation even with the application of high rates of the specific nutrient.

The basic criterion separating these two essentially grazing classes from Class VI is that they can be cultivated for an occasional crop, or cultivated for pasture establishment. Slope gradients and site characteristics restrict the suitability of cultivation on Class VI land.

Class IV

Land of low to moderate soil erosion hazard, subject to minor to moderate sheet, rill and gully erosion, where the existing and potential soil erosion can be controlled by land management practices. These land management practices will include establishment of improved pastures, stock control, application of fertilizer and where annual crops are grown, the establishment of a rotation system which will minimize soil erosion losses and maintain soil structure and fertility.

Class V

Land of moderate to high soil erosion hazard and/or subject to severe sheet, rill and gully erosion, where the soil erosion is controlled by the use of structural soil conservation measures, or by strict land management practices, in excess of the requirements listed for Class IV.
Where structural soil conservation measures are considered to be unsuitable, the following land management practices may be implemented:

1. Fencing out of eroded areas.
2. Revegetation, including reafforestation of eroded areas. Alternatively, in some situations, reduction of timber cover to improve grass cover is recommended.
3. Log or pole structures within eroding gullies.
4. Restriction or exclusion of stock.
5. De-watering systems.
6. Contour or deep ripping.

Land Suitable for Grazing

Class VI

Land not suited for any type of cultivation, but best suited to grazing. Soil erosion hazard varies from nil to high and the land is subject to varying degrees of soil erosion.

The class generally comprises land with a range of physical or climatic limitations which prevent cultivation for crops or pastures and restrict the use of soil conservation structural works as a means of soil erosion control.

These physical limitations may include one or more of the following:

1. shallow soils
2. high rock content (greater than 40 per cent of the surface area)
3. very high soil erodibility ratings
4. excess salt concentration
5. impeded drainage, high water tables or seepage flows
6. areas regularly inundated.
7. steep or awkward slope gradients, limiting the ability to install soil conservation structural works.

Land Best Protected by Green Timber

Class VII

Land which, owing to its high soil erosion hazard and severe site limitations, should best remain under green timber.
The distinctions between Classes VII and VIII are rather fine. Essentially, the difference is that Class VII land, when cleared (although it is contrary to the recommendations of the capability classification), will support a moderate level of production. The erosion hazard still remains high.

Production from Class VIII land is extremely low and environmental problems much greater.

In notified catchment areas, where Class VII and Class VIII lands are classified primarily on the basis of slope, they correspond to areas of protected land.

Other Land

Class VIII

Land generally considered to be unsuitable for any type of agricultural or pastoral production because of severe physical limitations. These limitations may include:

1. Steep to precipitous slopes (in most situations, slopes greater than 50 per cent).

2. High proportion of rock at or close to the surface (greater than 70 per cent of surface area).

3. Subject to permanent or seasonal inundation. Includes beds and banks of streams of fifth order or greater, swamps, lagoons, lakes, tidal flats, estuaries.

4. Areas of sand accumulation (e.g. inland and coastal dunes, beaches, etc.) with low fertility, low water holding capacity and liable to severe wind erosion when depleted of ground cover.
Theme 1B - Questions Posed And Responses From Working Groups

1. Do we have an understanding on information needs for resource collection to enable a uniform approach?

Yes, the new field survey terminology handbook is available. This provides a start towards a national approach although organisations will have differences according to their needs as to how they record and sort data. Data recorded needs to be objective as opposed to subjective field assessments.

2. How should we handle change in technology in land capability assessment?

This can be handled by collecting a minimum data set for later interpretation should technology change; class limits may later have to change to allow further interpretation.

3. What influence does management have on land capability assessment in drier climatic lands?

The influence of management is not likely to be any greater in drier climatic lands. The assessment of land capability should be carried out assuming whatever normal management practices are in use at the time of the assessment.

4. How far can land capability assessment be extended to arid and semi-arid lands?

Agro-climatic zones based on water balance models should predict how far land capability assessment for dryland annual cropping can be extended; historic land use is also an indicator.

5. On what basis do we assess land capability, on inherent capability or potential capability?

The assessment should be based on the inherent capability of the land and on proven agricultural practices in particular areas.

"Interactions between land and land use"

Itinerary

<table>
<thead>
<tr>
<th>Location</th>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wilsonton Motel</td>
<td>8.40</td>
<td>- 8.45</td>
</tr>
<tr>
<td>Wyreema</td>
<td>9.10</td>
<td>- 9.55</td>
</tr>
<tr>
<td>Wyangapinni</td>
<td>10.30</td>
<td>- 11.15</td>
</tr>
<tr>
<td>Brookvale Park</td>
<td>11.50</td>
<td>- 1.20</td>
</tr>
<tr>
<td>Goombungee</td>
<td>1.55</td>
<td>- 2.55</td>
</tr>
<tr>
<td>Pechey</td>
<td>3.20</td>
<td>- 4.05</td>
</tr>
<tr>
<td>Cabarlah</td>
<td>4.20</td>
<td>- 4.50</td>
</tr>
<tr>
<td>Wilsonton Motel</td>
<td>5.20</td>
<td>- 5.25</td>
</tr>
</tbody>
</table>

Forest basalts

Scrubby basalts

Lunch

Sandstone areas

Red soils

Refreshments
Theme 3. Producing the desired land data in a cost-effective manner  

J.A. Beattie  
University of Tasmania

Abstract

Land capability assessment (evaluation) for dryland annual cropping involves correlation of yield/performance, edaphically significant land qualities, and hazards of land degradation. Site productivity may be measured directly as crop yield under defined conditions. Because this is usually not possible for more than a small part of any landscape and results are site-specific, indirect means of assessment are necessary for extension of yield/performance results in a spatial framework of land qualities.

Relevant biophysical land qualities include those dependent on climate, such as radiation, temperature and moisture regime, as well as those dependent on conservative soil properties. These include aeration and physical rooting conditions; workability, trafficability and mechanization potential; erosion hazard, and conditions for germination and/or establishment. Procedures are discussed for the measurement of land properties by means of which the above land qualities may be assessed.

Other soil qualities such as nutrient supply, salinity, sodicity and pH-related toxicities are both more variable and more easily changed by management. Only soil acidity is readily recorded in routine work and may not be hazard-specific. Costs increase rapidly with laboratory analysis of increasing numbers of field samples. Therefore these qualities might be assessed more cost-effectively in relation to management input on individual farms, together with assessment of total soil degradation hazard.

The more conservative soil properties of edaphic significance may be conveniently and cost-effectively recorded in biophysical land resource surveys (soil or land system surveys) at scales for identification of management units (average 1:20,000). Within a given socio-economic framework such surveys are essential to provide the data base for land capability assessment (evaluation). Their cost-effectiveness depends on careful definition of objectives, specification of means and competent execution of work.

Cost-effective performance of land resource surveys requires adequate in-service training, supervision and quality control. These requirements are more readily and consistently met in units of sufficient size. This suggests that responsibility for land resource surveys should be vested in only one survey organization in each State.

1. Introduction

Soil is not the same as land, of which it is indeed only one of a number of characteristics (Brinkman and Smyth, 1973). It is however a land characteristic that is managed directly for the production of most
crops. Although crop production is influenced by other land characteristics which may dictate the range of crops that may be grown and may restrict the expression of intrinsic soil fertility there has been historical emphasis on the soil expressed in the development of soil science and of soil survey in particular as an essential input for land evaluation (FAO, 1983). There is a need to collect data for all relevant land characteristics, including soil, in producing the information base for land capability assessment (evaluation) for dryland cropping. This involves a range of disciplines and suggests the value of an integrated approach for cost effectiveness. However there still appears to be a good deal of uncertainty about what are the quantitative effects of significant, observable edaphic properties (Avery, 1962) by means of which important soil qualities for dryland cropping may be estimated although some work has been done in other areas, for example, in assessing soil capability for irrigated pastures (Loveday and Butler, 1962).

Land evaluation for dryland annual cropping requires correlation of land qualities with crop yields and land degradation hazards. Long-term records of crop yields are a better basis for capability assessment than estimation of land qualities via measurable land properties. If results of long-term crop and fertiliser trials were available for the whole of a given tract of land, analysis of these results would obviate the need for other surveys. In reality such trials are never continuous over a large area, and are always site specific, even in highly developed farm regions. Trials are of little value for direct prediction of crop performance on other sites. Nevertheless, no opportunity should be lost of recording site-specific crop yield data.

The extension of yield/performance experience requires knowledge of the spatial distribution of land described and recognisable in terms of qualities required for successful crop management. Thus land resource survey is a basic requirement. For dryland annual cropping such resource surveys must cover the climatic and soil factors. Factors such as transport costs to markets and other socio-economic considerations are also included in land evaluations. However I have assumed that I should limit my discussion chiefly to the production of biophysical data.

2. Crop Yield Data

The best sources are long-term (at least ten to twenty years) field trials on homogeneous, representative sites. The requirement for site homogeneity and representativeness means in practice that the results of past trials may not be very relevant. In any case they should be critically examined. Ideally, new trials should be established on sites representative of extensive land units. Techniques for establishment and management of field trials are well understood (Hauser, 1970). The spectacular advances in continuous recording devices linked to computer data files should also be utilized (Ross, 1984) for increased cost effectiveness.

Long-term field trials used to be fairly popular in Australia but seem to have lost favour for various reasons some decades ago. Most were probably poorly located and their logistics were difficult. Their role
should be given careful consideration in the future with a view to establishment of fully instrumented trials using the most modern equipment. Such an approach could prove to be very cost effective in producing good data for dominant land units and for future monitoring of performance.

Of lesser precision and reliability are yield statistics from the records of State departments of agriculture or of advanced individual farmers in the area to be assessed. It is difficult to use statistical yield information collected for political districts that are diverse in respect of land characteristics. Although analysis of such data may be unproductive of useful indications, it is worthwhile to carry out an inspection of it.

Crop sampling as part of a land resource survey can yield useful information. Although past history and management factors may be uncertain the information can be realistic. Departmental officers make regular estimates for the purposes of forecasting grain deliveries. To be relevant for capability assessment purposes such data would need to be related to indentifiable land units.

Yield data may be plotted directly on a map of land units, or yield tables for different crops may be prepared for each land unit, including means and standard deviations. Land units co-incident with consistently high yields would be assessed as highly suitable, and so on. Another approach is to calculate regression equations for crop yields and land qualities. This requires a lot of yield data from trials or farmers' fields together with estimates of land qualities. Again the relationships would be expressed in suitability or capability classes.

An essential precaution is the stratification of yield data in terms of input levels and detailed management practices, especially crop variety and fertilizers. Additional ratings for management and conservation would have to be derived separately. Complex relationships are the rule rather than the exception and correlations with environmental factors may be obscured by management differences. Even so this approach shows promise of providing accurate, quantitative estimates of the effects of different land qualities on crop yield and merits further development. In published work it appears that two to four land qualities may account for most yield variation in a given area (Young and Goldsmith, 1977; Radcliffe and Rochette, 1982).

3. Assessment of Land Qualities for Dryland Annual Cropping

Since direct association of crop yield data, land qualities and land units is not feasible over at least the greater part of areas of land for which capability assessments may be required, basic land resource survey is an inescapable task in most cases. The essential role of soil and other land resource surveys has been comprehensively discussed by FAO (1976) and Beek (1978, 1981a and 1981b). Descriptive or quantitative data are always site specific yet cannot be produced directly for more than a small fraction of the total area. Thus sites of data production must be representative, within practical limits of accuracy and precision, of areas at management scale. For greater cost effectiveness data collection sites must also be located on kinds of
land units at management scale that recur frequently or are themselves representative of larger areas within agroclimatic zones (FAO, 1983). The frame of reference for location of specific data sites in most countries is a soil or soil and landforms map. The data on which land evaluation or capability assessment has been based must be recorded in permanent and available form. Increasingly data are being digitized for storage in computer data files (Bie, 1975, 1980; Burrough, 1982, Kuilenberg et al., 1981). These include the basic soil or landforms map and agroclimatic data and may also include information on hydrology, vegetation, other land characteristics or survey data for land systems and facets. A permanent record of biophysical data permits re-appraisal of evaluations with changes in possibly less stable economic factors.

3.1 Climatic Factors

The measurement and/or collection and regular publication of climatic data has been the responsibility of the Australian Meteorological Bureau in the interests of the whole community and can usually be accessed at little cost by other agencies. Rainfall data have been recorded at numerous minor stations with greater or lesser reliability related to collection equipment and its siting and these may also be effectively collated (Nicolls and Aves, 1961). Fully instrumented meteorological stations are still relatively few in number in Australia so that for practical purposes only rainfall and temperature records are available for a large number of stations.

It has always been difficult to apply climatic criteria with precision. Climate can be very variable, particularly rainfall incidence, and data are deficient for management-scale application. On the other hand crop tolerance of drought, frost or wind varies widely as does farmer acceptance of hazard levels.

3.1.1 Land Qualities Dependent on Climate

Radiation regime is important in assessing production potential over very large areas but is not usually a differentiating land quality for land capability assessment within small areas except where topography exerts a strong effect on radiation through cloudiness or slope aspect. Day length or photoperiodicity is another factor whose effects are expressed very broadly but which must be taken into account in the introduction of new crops or cultivars.

Temperature regime also is normally a differentiating land quality only between large regions but significant changes may occur with altitude over short distances and slope aspect is a significant factor in subtropical and temperate areas, especially in relation to crop maturity.

Total moisture is intended to be a measure of the failure of available moisture supply to meet the physiological crop requirement assessed in relation to climate. Since effects of moisture stress are fairly crop-specific it may be better to make assessments of moisture supply during critical periods for each crop (Doorenbos and Kassam, 1979). Drought hazard is a measure of the likelihood of soil moisture falling low enough for long enough to cause crop death. Again the length of this
period varies with the crop. The period of greatest risk for dryland annual crops covers emergence and establishment. Various forms of the ratio of rainfall to evapotranspiration have been used for general prediction of moisture regime and the moisture supply index of Doorenbos and Massam (1979) is a recent example of developments in this respect. More local effects are related to soil, landform and hydrology via soil depth and clay content, local run-on or run-off, seepage or water table. Rating of moisture supply is an important aspect of land capability assessment for dryland annual cropping in areas receiving a mean annual rainfall below about 1200mm. There is probably enough data on specific crop requirements coupled with meteorological tables to allow broad assessments to be made. A modern approach on this level involves the identification of agroclimatic zones (Beek et al., 1981; FAO, 1978). These are combinations of major climates and growing periods in days and each agroclimatic zone is suitable for a limited range of crops or cultivars. Important local climatic variations due to terrain may be superimposed on the broader agroclimatic zone rating but should be handled in relation to land mapping units in the same way as other land qualities.

A system of agroclimatic classification has been developed (FAO, 1980; Higgins and Kassam, 1982) in which major climates have been defined. However significant local effort may be required for determination of growing periods following the recommended method (FAO, 1983). This includes seven distinct aspects of data collection or calculation:

1. The growing period is the sum of individual 10-day periods in which mean daily temperature equals or exceeds $50^\circ C$.

2. The growing period commences when precipitation equals or exceeds half potential evapotranspiration ($P > 0.5PET$).

3. A normal growing period includes at least one 10-day humid period in which rainfall exceeds potential evapotranspiration ($P > PET$).

4. The "end of rains" is the time at which precipitation falls below half potential evapotranspiration.

5. The growing period ends at the end of rains plus the time taken for the crop to use stored soil moisture; at the end of the humid period the soil moisture store (mm) is added to successive 10-day moisture deficits ($PET - P$) until residual stored moisture is below that needed to raise $P$ to 0.5 PET.

6. The normal growing period is the sum of the 10 day periods from its beginning (2) to its end (5), less periods below $50^\circ C$ mean daily temperature.

7. An intermediate growing period is one without a humid period (3) so that there is no reserve of soil moisture and therefore the growing period ends at the end of rains (4).

Isolines of growing periods may be drawn at 75 to 90 days and at 30-day intervals to 330 days and superimposed on a map of major climates to define agroclimatic zones, e.g. warm subtropics (summer rainfall) growing period 90-120 days.
An important aspect of climatic regime may be referred to as "conditions for ripening" (FAO, 1983) describing a period of crop-specific duration at the necessary times of the year that is:

1. dry (little or no rainfall),
2. with sufficient hours of sunshine, and with
3. temperatures above or below required values.

Aspect is so closely related as to provide the basis for a rapid indirect method of assessment. This involves defining a limiting slope angle. For all slopes above this angle facing north-east to north the assessment would be upgraded while that of areas facing south-west to south would be downgraded. For greater precision, the modifying effects of aspect and slope angle on direct solar radiation may be calculated from astronomical data. For maximum specificity in relation to high-value, specialised crops, measurements of radiation and temperature may be made on slopes of different angle and aspect. These measurements, after correlation with crop performance and reference to local experience, may then provide the basis for extrapolation of assessments over an area using contour maps.

Flood hazard is another climate-related land quality and may involve damage to soil and structures as well as crops. Landform is the determinant of flooding against a background of hydrology and climate. The hazard may be measured in terms of the period of inundation in days and the flood frequency, or probability of occurrence of damaging floods. A damaging flood is one that destroys or severely damages a crop, the land or man-made structures. Flood hazard can seriously downgrade the assessment of otherwise good land and tends to be overlooked if flood frequency is low. Although flood frequency is usually greatest on flood plains, a severe hazard may be present on gently sloping lands, fronting more hilly terrain due to flash flooding. Landforms such as alluvial fans or coalesced fan aprons against a backdrop of more elevated hilly terrain should be examined closely for evidence of recent events in the course of soil or land survey.

3.2 Soil Factors

There has been general recognition of the prior need to produce data on soil properties that determine more conservative soil qualities and influence the outcome of attempts to improve less conservative soil qualities dependent on chemical properties that can be modified relatively easily "out of the bag". Such properties are mainly physical (Beckett and Webster, 1971).

3.2.1 Oxygen Availability to Roots

Low levels of oxygen in the soil air may follow excessive rainfall or sites of slow disposal of excess water by runoff or infiltration where the soil has a low air capacity between field capacity and saturation.
The problem may be worsened by the presence of a water table at shallow depth. This quality is affected by landforms, soils and hydrology. This limitation is common on heavy clay soils and strongly duplex soils on low-angle foot and toeslopes in southern Tasmania. Surface drainage may be provided but this involves both capital and maintenance costs.

Five methods of assessment are available:

1. periods with redox potential (Eh) below 200mV,
2. periods of continuous water saturation,
3. soil colour and mottling,
4. soil drainage class,
5. inference from native vegetation.

Method (1), although reliable, is not practicable for routine surveys. It may be used for greater precision where a severe problem exists. Method (5) alone is less reliable but is possible by airphoto interpretation (Carroll et al., 1977). The recommended routine procedure is to combine drainage class (4) with soil colour and mottling (3) and an estimate of periods of water saturation (2) by monitoring ground water level at different times during the growing season. Soil colour and mottling are not always closely related to a current condition but may reflect an earlier one. Although an important soil quality, crop-specific yield response data on oxygen availability remain to be determined.

3.2.2 Rooting Conditions

This quality may be assessed in terms of effective soil depth and ease of root penetration. Effective depth may not be readily measured and may vary with crop characteristics. It may be recorded as the depth to rock, gravel, hardpan or toxic layer. However in many situations identification is not so easy. Root penetration is easier in soils of light field texture or clay soils of strong, stable, fine to medium pedality. It is inhibited in apedal or coarsely pedal soils of firm consistence and high bulk density as well as by the presence of stone or coarse gravel. The effective depth of many strongly duplex soils with dense clay subsoils may be easily overestimated. The penetration of a few roots via widely-spaced, vertically-orientated, planar voids may make little contribution to crop performance. This is another problem for investigation on many such soils in south-eastern Tasmania devoted to annual cropping of wheat, oats and barley. Their effective depth may not extend beyond the upper subsoil and it would be reasonable to record this in the absence of contrary indications. The quality is usually included in assessments because of its obvious effects but its assessment from standard soil descriptions may not be as straightforward as claimed, at least for many Australian soils.

The soil depth for rooting may be recorded simply as effective soil depth (cm). Ease of root penetration may be assessed via several soil physical properties. Amongst these are bulk density which may be
accurately measured (Loveday, 1974) and penetrability of the soil in moist condition to a cone penetrometer (Davidson, 1965). The large numbers of bulk density data needed would be justifiable only in intensive studies. Penetrometer data can be collected very rapidly but require standardization against moisture status. Field assessment of the latter by the method of Butler (1955) may be adequate.

Classes combining field texture, pedality and consistence have been devised (FAO, 1983) to which the mean percentage of stone and gravel above a limiting horizon may be added. Assessment of rooting conditions may thus be based on degree of limitation to root penetration (Table 1), percent stones and gravel, penetrability and bulk density.

3.2.3 Soil Workability and Trafficability

This depends on interrelated climatic and soil properties including texture (field or laboratory), organic matter, pedality, consistency (upper and lower plastic limits) interacting with rainfall and amount of stones or coarse gravel in the surface layer. Workability (and trafficability) may be the most important soil factor affecting land use. Thomasson (1982) has developed a rating scheme expressed in "workability days" calculated by subtracting the number of days after rainfall that must elapse before the soil may be cultivated successfully, together with the number of days when the soil is too dry, from the total number of days available for soil preparation between crops. Less directly workability may be assessed in terms of field texture, pedality and consistence of the topsoil. Classes may be downgraded if stones or boulders are excessive (e.g. more than 10% cover of surface).

Soil workability is an important quality in areas of high rainfall or where clay content is high or dominated by the presence of montmorillonitic clays. It is also related to energy use in tillage operations as in the expressions "light" versus "heavy" soils.

3.2.4 Potential for Mechanization

Land conditions which limit the use of mechanized farm equipment are slope angle, rock outcrop or rock at shallow depth, stoniness and heavy plastic clay. Data on these properties may be collected routinely in soil survey. Classes have been proposed (Table 2) by FAO (1983).

3.2.5 Erosion Hazard

It is over fifty years since official recognition of the serious effects of accelerated soil erosion in the United States. More recent treatments include those of Hudson (1981) and Kirby and Morgan (1981). Fundamental sedimentological relationships on slopes have been investigated by Moss and Walker (1978) and Rose (1984) has discussed recent advances in research on soil erosion processes.
### TABLE 1. ASSESSMENT OF ROOT PENETRABILITY OR WORKABILITY

<table>
<thead>
<tr>
<th>SOIL PROPERTY</th>
<th>CLASS</th>
<th>1 Easy</th>
<th>2 Moderate</th>
<th>3 Difficult</th>
<th>4 Very Difficult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistence</td>
<td>Loose, very friable, friable</td>
<td>Firm</td>
<td>Very firm</td>
<td>Very firm</td>
<td>Extremely firm (plastic, very stiff and sticky when wet; very hard when dry).</td>
</tr>
<tr>
<td>Pedality</td>
<td>Any</td>
<td>Any</td>
<td>Moderate or strong medium or fine blocky; any class of granular or crumb</td>
<td>Coarse or very coarse blocky; any class of prismatic, columnar or platy; weak grade of any other type; apedal</td>
<td>Any other than as listed for very difficult</td>
</tr>
<tr>
<td>Field texture</td>
<td>All sands and loamy sands; many loams; some sandy clays and clays where dominantly kaolinite and sesquioxides</td>
<td>Range from sandy loams to clays</td>
<td>Mostly clays and sandy clays, some sandy clay loams</td>
<td>Clays, usually heavy clays</td>
<td></td>
</tr>
</tbody>
</table>

* After FAO (1983).
TABLE 2. ASSESSMENT FOR MECHANIZATION POTENTIAL

<table>
<thead>
<tr>
<th>LAND CHARACTERISTIC</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope angle, degrees</td>
<td>5</td>
<td>10</td>
<td>18</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Slope angle, percent</td>
<td>9</td>
<td>18</td>
<td>32</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Rock (outcrops &amp; boulders)</td>
<td>1</td>
<td>4</td>
<td>10</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Stone % topsoil</td>
<td>&lt;1</td>
<td>&lt;5</td>
<td>&lt;15</td>
<td>&lt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Plastic heavy clay</td>
<td>absent</td>
<td>absent</td>
<td>present</td>
<td>present</td>
<td>present</td>
</tr>
</tbody>
</table>

* After FAO (1983)

Assessment of erosion hazard requires measurement of the susceptibility of land to erosion as well as consequential productivity losses. Soil loss has been related to rainfall erosivity (climatic records), soil erodibility (maximum soil loss), slope length and gradient, effects of crop management and conservation practices by Wischmeier and Smith (1978) in formulating the Universal Soil Loss Equation (USLE):

\[ A = RKLSCP \]

where

\[ A = \text{soil loss (t/ha/year)} \]
\[ R = \text{rainfall erosivity} \]
\[ K = \text{soil erodibility} \]
\[ L = \text{slope length factor} \]
\[ S = \text{slope gradient factor} \]
\[ C = \text{crop management factor} \]
\[ P = \text{conservation practices factor} \]

The reference soil loss is \( A = R \times K \) from a bare soil surface of standard slope angle and length. This is reduced by crop management in providing protection from raindrop impact and overland flow effects and by conservation practices modifying the slope length and gradient factors. The C and P factors are derived from specification of land utilization type while the R, K, L and S factors are land characteristics related to land units. The USLE was developed on data measured in the United States and may not be directly applicable to very different climatic and soil conditions. This has been found to be the case particularly for the tropics and sub-tropics (Hudson, 1981) and a different model developed in Zimbabwe (Elwell, 1980; Elwell and Stocking, 1982) may be more widely relevant as a Soil Loss Estimator for Southern Africa (SLEMSA).

Alternatives to the massive task of collecting base data for operation of the USLE in Australia are being investigated (Rose, 1984). The many plot years of data from the run-off and soil-loss work of the N.S.W. Soil Conservation Service represents a significant resource for model testing.
Until an effective predictive model (or models) is available the practical approach will be to continue data collection on present-day erosion in relation to soil, slope and land utilization type in the course of field surveys. Rainfall erosivity may be assumed to be practically uniform provided study areas are not too large. Classes of erosion hazard may be defined in terms of soil and slope in relation to the severity of observable erosion. Where present-day erosion is moderate to severe the erosion hazard must be assessed as high to extreme calling for changed land use, special conservation practices or major land improvements. In the absence of visible present-day erosion, assessment can be based on soil and landform characteristics by analogy with areas where erosion is evident.

There may be a significant wind erosion hazard for soils of light sandy textures and soils of heavier texture, with strong aggregation in the medium to fine sand grades, used for dryland annual cropping in areas where land is prepared for seeding at times of low rainfall and strong wind. In the absence of a suitable predictive model the practical approach to hazard assessment may be similar to that suggested for water erosion using data from routine survey.

3.2.6 Conditions Affecting Germination and/or Establishment

Assessment of this soil quality has been covered in part because conditions of workability also relate to those for a good seedbed and because erosion hazard, affecting seedbed stability, is related to both germination and establishment. Important soil properties not dealt with are those of surface sealing and hard setting exhibited by many Australian soils (Arndt, 1965; Northcote, 1971). Assessment may be based on pedality and consistence, susceptibility to surface sealing and amount of coarse gravel in the surface (Table 3). These data are readily observable in the course of routine survey. An "index of crusting" proposed by FAO (1979) is based on the ratio of fine silt (2-20 μm) and coarse silt (20-0 μm) to clay and organic matter,

$$\text{Index of Crusting} = \frac{15Z_f + 0.75Z_c}{C + (10 \times OM)}$$

where $Z_f$ = fine silt, %
$Z_c$ = coarse silt, %
C = clay, %
OM = organic matter, %

3.2.7 Other Soil Qualities

These include nutrient status (availability and retention), salinity, sodicity, and pH-related toxicities. Of these qualities only the last may be recorded in routine survey work as pH but this does not permit definite identification of the hazard. Collection of field samples and their laboratory analysis greatly increases survey costs. Only very limited sampling of management units is usually possible and the high degree of variability of these soil properties renders uncertain their prediction on a limited number of samples, permitting only broad and heavily qualified statements to be made. Much of the criticism of soil surveys has been made concerning the heterogeneity of mapping units in respect of such properties.
### TABLE 3. ASSESSMENT OF CONDITIONS FOR ESTABLISHMENT (SUDAN)*

<table>
<thead>
<tr>
<th>SOIL PROPERTY</th>
<th>CLASS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedality 0-15cm</td>
<td>Apedal (sands), coarse crumb or granular; moderate</td>
<td>Coarse subangular or granular; angular</td>
<td>Strong coarse angular blocky; angular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistence 0-15cm</td>
<td>Loose or very friable moist</td>
<td>Friable to firm</td>
<td>Firm to very firm moist, moist, hard to extremely firm</td>
<td>Extremely hard firm moist, moist, hard to extremely firm</td>
<td></td>
</tr>
<tr>
<td>Susceptibility to surface sealing</td>
<td>None</td>
<td>Slight</td>
<td>Moderate</td>
<td>Strong</td>
<td></td>
</tr>
<tr>
<td>Coarse gravel % surface cover 3</td>
<td>3-15</td>
<td>15-40</td>
<td>40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* After FAO (1983)

On the other hand these essentially chemical-biological soil properties are readily modified by modern management techniques available for dryland annual cropping in Australia including the use of fertilizers and other amendments. (Salinity and sodicity are not serious hazards in areas where dryland annual cropping is possible.) Thus they may not be regarded as limiting in land evaluation for dryland annual cropping other than in extreme situations. It is for these reasons that data collection for their assessment may not be considered as an essential aspect of soil or land resource surveys for land evaluation, but rather as an ongoing management input for individual farms. If a tract of land is given a high assessment in terms of climatic and physical qualities and socio-economic factors are favourable it is not likely to be discarded in consideration of qualities that can be readily improved.

#### 3.2.8 Soil Degradation Hazard

This refers to physical, chemical and biological degradation of soil properties, including salinization and erosion.
Physical degradation of the soil surface may be evident in slaking, sealing or crusting while in the profile as a whole there may be development of unfavourable pedality, compaction, porosity and permeability. Such degradation may affect oxygen availability, rooting conditions, conditions for germination and establishment and increase the hazard of erosion. It can be monitored via changes in penetrometer resistance, bulk density, porosity, infiltration capacity and permeability. Chemical degradation refers to adverse changes in chemical properties, including salinization, as a result of poor management of fertilizers and soil hydrology, and affects nutrient availability as well as leading to direct toxicities via acidification. Biological degradation refers to decline in soil organic matter whose adverse effects include reduced nutrient availability and retention, and physical deterioration exacerbating erosion hazard.

According to FAO (1983) soil degradation hazard assessment may be made for each form of significant degradation or in the form of an overall measure called the rest period requirement or cultivation factor. This is the number of years under cultivation expressed as a percentage of the total cycle or a measure of the intensity of arable use.

\[
R\% = \frac{C}{C + F + L} \times 100
\]

where

- \(C\) = years of cultivation
- \(F\) = years of fallow
- \(L\) = years of ley or other non-arable use.

It is a measure of the rest period requirement of the soil to maintain it in a long term steady state free from organic matter or nutrient decline, at a reasonable level of productivity in relation to inputs, and in a physical condition for minimal erosion hazard.

4. Basic Land Resource Survey

Land capability assessment (evaluation) includes the basic land resource surveys (soil survey, Dent and Young, 1981, land system survey, e.g. Howe (1976) as well as climatic and other records) which are major data sources. Land evaluation as practised in most countries is neither a desk nor a consultative exercise but requires field survey and other data collection tasks (McRae and Burnham, 1981). The data requirement including scale and sampling intensity must be decided in terms of specific objectives (Dibbons, 1981). An agreed specification is an essential prerequisite for a cost-effective outcome (Western, 1978). The kinds of data that can be collected in basic surveys for dryland annual cropping are listed in Table 4. I propose to deal only with surveys of soils and landforms. Their role in land evaluation was reviewed by McDonald (1975).
TABLE 4. DATA ACQUIRED FROM BASIC SURVEYS*

SURVEYS OF LAND RESOURCES

- Soils
- Landforms
- Climate (agroclimatology)

SURVEYS OF LAND USE

- Present land use
- Present agricultural systems incl. crop performance etc.
- Agricultural infrastructure incl. facilities, extension staff, research stations etc.

ECONOMIC INVESTIGATIONS

- Labour, availability and cost
- Markets
- Prices
- Farm economics
- Accessibility, transport systems

SOCIOLOGICAL INVESTIGATIONS

- Population
- Sociology
- Farmer attitudes

* After FAO (1983)

The scale and intensity of soil survey are closely related and survey costs escalate sharply as scale increases (Figs. 1, 2, after Bie and Beckett, 1970). Some information for surveys conducted at scales appropriate for the average density of observations necessary to provide data on which to base land capability assessment for dryland annual cropping is given in Tables 5, 6 and 7, after Dent and Young (1981).

The scale of soil survey should match the intensity of other investigations. It is no more cost effective to carry out detailed soil surveys in isolation than it is to carry out an intensive land use study on a background of reconnaissance soil survey. If time or funds are not available for production of all the data required decisions must be made on survey priorities at the outset.

The data required from new land resource surveys in a land capability assessment project may differ according to the level of data already available. The latter may vary from reliable maps of soils, landforms, etc., at required scale and intensity to a situation where such information is either not available or where information is unreliable or at too small scale. In the unlikely event in Australia that a detailed basic soil survey has been completed in the past it is likely to be deficient for the purpose of a modern land evaluation. Some
supplementary surveys will almost certainly be needed to assist interpretation of existing maps and for collection of further field data for assessment of land qualities.

In the absence of basic soil or land resource survey data and where neither time nor funds are available for their acquisition, a strictly qualified capability assessment may be made on a limited range of site-specific soil and environment factors (Howe, 1976; Beattie, 1978; Howe and Gibbons, 1982). A less demanding, although negative, limitations approach may be followed in setting up criteria (Cocks and Basinski, 1978). Factors should be selected for their broad edaphic significance. Under time and funding constraints data should be capable of acquisition quickly and economically by personnel with a minimum level of technical expertise. Such factors might include: slope angle, length and aspect; effective soil depth for rooting; field texture of cultivated layer; and dispersivity of surface and subsurface layers.

**Figure 1** Relationship between intensity of soil survey in man days and map scale (After Bie and Beckett, 1970).
FIGURE 2  Relationship between the cost of soil survey and eventual map scale (After Bie and Beckett, 1970).

(The broken lines are from Veenenbos (1957) graphs)
<table>
<thead>
<tr>
<th>SCALE</th>
<th>MEAN NUMBER OF OBSERVATIONS PER 10ha (at 1 per cm² of map)</th>
<th>AREA MAPPED** per MONTH (ha) (20 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:5,000</td>
<td>40.0</td>
<td>225-450</td>
</tr>
<tr>
<td>1:10,000</td>
<td>20.0</td>
<td>400-750</td>
</tr>
<tr>
<td>1:20,000</td>
<td>2.5</td>
<td>900-2000</td>
</tr>
<tr>
<td>1:25,000</td>
<td>1.6</td>
<td>1200-3000</td>
</tr>
<tr>
<td>1:50,000</td>
<td>0.4</td>
<td>(25=75km²)</td>
</tr>
</tbody>
</table>

* After Dent and Young (1981), in part.

** Rough estimates only without allowance for bad weather, illness, or mechanical breakdown.

---

<table>
<thead>
<tr>
<th>SCALE</th>
<th>AREA OF WHOLE PRINT (km²)</th>
<th>WORKING AREA ON ONE PRINT (km²)</th>
<th>NUMBER OF PRINTS PER 100km²</th>
<th>GROUND EQ. OF 1mm (m)</th>
<th>GROUND EQ. OF 1cm² (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:5,000</td>
<td>1.3</td>
<td>0.8</td>
<td>240.0</td>
<td>5.0</td>
<td>0.25</td>
</tr>
<tr>
<td>1:10,000</td>
<td>5.2</td>
<td>3.3</td>
<td>60.0</td>
<td>10.0</td>
<td>1.0</td>
</tr>
<tr>
<td>1:20,000</td>
<td>21.0</td>
<td>13.0</td>
<td>15.0</td>
<td>20.0</td>
<td>4.0</td>
</tr>
<tr>
<td>1:25,000</td>
<td>33.0</td>
<td>21.0</td>
<td>10.0</td>
<td>25.0</td>
<td>6.25</td>
</tr>
<tr>
<td>1:50,000</td>
<td>131.0</td>
<td>84.0</td>
<td>2.4</td>
<td>50.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

* After Dent and Young (1981), in part.
TABLE 7: SOIL SURVEY SCALE*

<table>
<thead>
<tr>
<th>SCALE</th>
<th>Mean distance (m)</th>
<th>Survey Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:5,000</td>
<td>0.25</td>
<td>50.0</td>
</tr>
<tr>
<td>1:10,000</td>
<td>1.0</td>
<td>100.0</td>
</tr>
<tr>
<td>1:20,000</td>
<td>5.0</td>
<td>200.0</td>
</tr>
<tr>
<td>1:25,000</td>
<td>6.25</td>
<td>250.0</td>
</tr>
<tr>
<td>1:50,000</td>
<td>25.0</td>
<td>500.0</td>
</tr>
<tr>
<td>1:250,000</td>
<td>6.25 (km²)</td>
<td>2.5 (km)</td>
</tr>
</tbody>
</table>

* After Dent and Young (1981), in part.

These are related to land qualities of erosion hazard, water storage capacity, nutrient supply and conditions for germination and establishment. Limiting values may be assigned more or less arbitrarily at first and refined in the light of experience.

Adoption of such a procedure would be regarded as unsatisfactory even if demanded in the context of extreme political urgency and this should be stipulated on the record by any unit assigned to such a task. Procedures which involve rapid scanning of districts by ad hoc multidisciplinary committees to arrive at a direct land evaluation by consensus should be unacceptable under any circumstances. This comment is also applicable to the practice of applying the USDA system of land classification (Klingebiel and Montgomery, 1951) or some variant of it (Canadian Land Inventory, 1965; N.Z. Ministry of Works, 1974; N.S.W. Soil Conservation Service, 1975; Bibby and Mackney, 1977) in a way that can only be described as "eyeballing". Such practice ignores the pyramidal structure of the scheme in which soil mapping units are aggregated to produce capability units, capability units to produce subclasses and subclasses to produce the eight capability classes of the highest category.

Australian Soil Survey

Modern soil survey in Australia began with the establishment in 1926 of the Division of Soils of the then, Council for Scientific and Industrial Research. The first surveys were commissioned to assist in solving problems of waterlogging and salinity in recently irrigated...
soils along the lower Murray River in South Australia. Work continued with the same objective in the detailed mapping of other irrigation areas. However in the last fifty years soil surveys have been undertaken by a number of organizations using different procedures and legends at different scales with diverse results (Beckett and Bie, 1978). In very few, if any, instances has a soil survey been carried out to a specification agreed upon after adequate discussions involving instigator (supplier of funds), surveyor and user (if different from funding agency). It is not surprising that the quality (uncontrolled) adequacy and relevance (unexplored) of the data produced by many soil surveys have been found, in retrospect, to have been unsatisfactory. As a rule there was little attempt to interpret the soil survey data for the user. A rare ad hoc exception enjoyed some success (Butler, 1949). General lack of satisfaction on the part of those to whom it was assumed that the surveys would be useful, ipso facto, and transferred disillusionment in the profession led to the almost complete abandonment of soil survey by the CSIRO Division of Soils more than twenty years ago. Present policy is still that the Division should not engage in such work.

Criticism of soil surveys for alleged failure to provide solutions to some very complex multidisciplinary problems of land use is not unique to Australia (e.g. Gersmehl, 1980) but criticism has been answered more successfully in other countries, most recently by the Soil Survey of England and Wales.

For some time few (Northcote, 1962) dared to mention the disgraceful term "soil survey" other than in terms of scornful derision and some (Butler, 1962) argued the futility of soil survey on the international scene with consequences figuratively similar to those suffered by a more ancient prophet on emerging from a comparably barren wilderness (scientifically speaking). In a presumptuous display of temerity (Beattie, 1974) the question was put once more and elicited a response in the form of the single resolution sent to the Australian Agricultural Council from the National Soil Conference held at La Trobe University. This was quickly followed by the 1975 Working Party on Soil Survey (CSIRO, Canberra) an excellent review by McDonald (1975) and a series of contributions to the Collaborative Soil Conservation Study, 1975-77 (Burrough, 1978; Christian, 1978; Hallsworth, 1978a, 1978b). A further development was the setting up of a technical committee which has become the Australian Soil and Land Resource Survey Committee, reporting to the Standing Committee on Soil Conservation. The ASLRC has sponsored production of the Australian Soil and Land Survey Handbook of which part one, Field Handbook, edited by R. C. McDonald et al, was published earlier this year. Volumes two and three on methodology and laboratory analysis are in preparation.

Moreover there have been very significant advances in soil survey methodology (Soils Staff, USDA, National Soils Handbook, Fifth Draft, in preparation) and interpretations (Olson, 1981; Schreier and Zulkifi, 1983; Wright, 1984). The use of computers for data analysis and storage has also seen rapid advances (Webster et al, 1979; Burgess and Webster, 1980a, 1980b; Burgess et al, 1981; Burrough, 1982, Rogoff, 1982; Thompson et al, 1982).

Thus the present is an opportune time for discussion of the role of soil and land survey in cost-effective production of data needed for land capability assessment for dryland annual cropping.
Cost-Effective Conduct of Land Resource Surveys

Aspects of cost-effective data production have been pointed out in the foregoing discussion in relation to yield/performance of crops on different land units, acquisition of meteorological data for climatic assessments, and assessment procedures for land qualities relevant for dryland annual cropping.

Much thought and careful analysis of published information has been applied to the elements of cost effectiveness of soil survey (Bie and Beckett, 1970, 1971; Burrough, Beckett and Jarvis, 1971a, 1971b, 1971c; Beckett and Burrough, 1971a, 1971b) at scales from 1:20,000 to 1:70,000. Cost effectiveness and quality may both be assessed in terms of reliability and usefulness of the survey. In brief, a successful outcome depends on careful definition of objectives, specification of the means of their achievement and competent execution of work in the minimum necessary time.

Costs of Soil Survey

The costs of soil surveys covering a wide range of scales has been discussed in some detail by Bie and Beckett (1970) and some further costs of Australian surveys have been noted by Hallsworth (1978). The main cost element in all cases is that of staff salaries and wages and staff-related field costs such as travelling allowances which together account for about 70-80% of total costs. These costs are related to the scale of mapping (Figures 1, 2). Other cost items include headquarters support staff, equipment of all kinds including airphotos, laboratory analysis, cartography, printing and buildings (rent or amortized costs). Dent and Young (1981) basing their data partly on the work of Bie and Beckett (1970, 1971) have tabulated survey costs per square kilometre in relation to mapping scale (Table 8). The estimated 1980 cost of the 1:20,000 National Co-operative Soil Survey of the United States was about $A2.50 per hectare.

Table 8. TIME AND COST OF SOIL SURVEY*

<table>
<thead>
<tr>
<th>SCALE</th>
<th>1:10,000</th>
<th>1:25,000</th>
<th>1:50,000</th>
<th>1:250,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man·days/km²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost (1980 $A/km²) at $50,000/man-year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA estimate at 1:20,000 scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* After Dent and Young (1981), in part.
Apparently the description of soil surveys as cost exercises is fallacious. At $2.50 per hectare in 1980 the cost was very small compared to even a single item of farm running costs such as superphosphate and minute in relation to the total per hectare cost of producing a wheat crop.

Of course costs have often been quoted in relation to government organizations enjoying continuity of work and perhaps some costs may not have been charged. Nevertheless, consultant firms that do have to charge true costs (Western, 1978) appear to be very competitive even in relation to more expensive overseas work.

Cost-Benefit Analysis of Soil Surveys

Precise data on cost-benefit analysis of soil surveys are more difficult to find in the literature. A famous and often-quoted reference is that of Klingebiel (1966). As the then, Director, Soil Survey Interpretation, Soil Conservation Service, USDA, he should have known what he was talking about when he detailed both positive returns from the use of soil surveys and cost savings from avoidance of unsuitable soil conditions in planning developments. Cost-benefit ratios over a 25-year amortization of survey costs ranged from 1:46 for low-intensity land use, to 1:61 for medium-intensity, to 1:123 for high-intensity land use. This means in the worst case that benefits should exceed survey costs within a year of the results being applied. Even if case histories such as those selected were relatively rare, there would still seem to be ample reason for discarding the peculiarly Australian shibboleth that "soil surveys are useless".

Technical Training for Soil and Land Resource Survey

Whatever combination of techniques is adopted, or dictated by circumstance, in the production of a data base for land capability assessment, a certain minimum level of expertise is demanded of staff assigned to tasks of collecting field data, analysis of laboratory samples and interpreting data for assessment of land qualities. If this expertise is lacking, the cost effectiveness of the whole operation is lost immediately in that results will either be useless or, worse, misleading. If the latter results in loss to a user entitled to place reliance on the information supplied the survey organization may well be liable for damages in the absence of a disclaimer. There have already been successful legal challenges to government land use decisions.

A high level of training, operator skills and experience is essential for making and interpreting soil and land surveys and in acquisition of crop performance data. Degree training in Australian universities has not provided more than a base on which professional expertise can be built. Effective in-service training and assessment of recruits, close supervision of inexperienced field operatives and a regular system of data checking at all levels is necessary for maintenance of professional standards on which validity of results depends. Only by such means can reliable output be ensured and only reliable output is worth testing for cost-effectiveness. These requirements are not being adequately or
uniformly met by most organizations responsible for soil and land surveys in Australia. It is clear that effective liaison and co-operative action amongst different agencies will be necessary if progress is to be made.

The existing, often fragmented, situation of non-viable units (non-viable by reason of staff numbers and back-up facilities, or inadequate staff training, or both) should not continue. In the interests of efficiency and professional standards responsibility for the conduct of soil and land resource surveys should be vested in a single organization in each State, operating as an independent branch or division, work priorities being recommended by a separate committee representative of those to whom such information is necessary.

References


Canada Land Inventory (1965). Soil capability classification for


Theme 3 - Questions Posed And Responses From Working Groups

1. Does soil and land survey have a role in production of land data for assessment of land capability for dryland annual cropping? If so, how essential is this role?

There was unanimous agreement that soil and land survey is an essential prerequisite for the assessment of land capability, however, the mapping scale and survey site density will depend on the objectives of the assessment and the time available. As a general rule, the more definitive the capability assessment required, the more detailed the soil or land data base should be. The user should also be made aware of how the soil/land data base has been prepared, including an assessment of reliability preferably on a statistical basis. Land capability assessment for more specialised crops may necessitate the involvement of specialists, e.g. hydrogeologists not usually part of any soil/land survey team.

2. What physical, chemical or biological soil or land properties can and should be recorded in soil or land surveys for interpretation of edaphic qualities?

There was strong feeling that a minimum data set for soil and land survey should be developed and introduced on a national basis and it is hoped that the Methodology Handbook will provide specific recommendations in this area. Nevertheless surveyor and user/requester should discuss together what parameters are most important to record for the capability assessment and the recording of data in excess of these needs and any minimum data set would be up to the discretion of individual organisations.

It was recognised that there should be more emphasis on recording soil/land properties important in erodibility assessment. The importance of soil morphological properties was also highlighted as crop performance assessments rely largely on these features. For dryland cropping assessments, the most important soil/land properties to record were thought to be available water capacity; maximum soil depth; maximum rooting depth; texture and trend with depth; coarse fraction percentage; soil and site drainage; slope angle and length and aspect (in temperate areas). Quantitative laboratory measurements, for example available water capacity, should be carried out at representative sites for inference across similar areas. Attributes recorded qualitatively should also be rated on an ordinate scale to aid in interpretation more objectively by computer.

3. Is standardization of procedures and of their performance desirable? If so, how might this be approached?

Standardisation in data recording and survey methods was seen as desirable but cannot be too rigid. To achieve at least a more standard approach to soil and land survey, it is important that survey agencies contribute to the production of the Handbooks instigated by the ASLRC when asked for comments and actively adopt methods in the Handbooks when they become available. The
involvement of outside persons in local workshops arranged by State organisations would assist in standardising of approaches in survey/capability assessment methodology. Concern was expressed that a flow chart or framework for the conduct of surveys would not be in any of the Handbooks. Similarly, it was thought that information on how to interpret soil properties in terms of productivity needed to be included in one of the Handbooks even though it would be difficult to standardise interpretation for the purpose of land capability assessment on a national basis.

4. How can professional training, supervision of staff and quality control of survey work be provided?

Ideally professional training in soil and land survey should be provided through a national pedological institute and uniform supervision and quality control provided by co-ordinating surveys through a national body. However, given the present situation that training is mainly done in-service after graduation, participants favoured the development of short-term training avenues; for example staff exchanges between organisations on a project basis of up to 6 to 12 months duration; refresher courses at suitable tertiary institutions and the development of cadetship/apprenticeship schemes between tertiary institutions and survey agencies.

The inadequacy of current soil classification systems and correlation in soil classification in Australia were seen as major limitations to achieving adequate quality control in surveys and the ability to transfer data nationally. The use of non-professional staff with adequate supervision was not thought to be as great an influence in maintaining quality control as the increasing use of consultants to carry out surveys. Quality control was also seen as a matter for more follow up with users of survey/capability assessments and for more contact between field operators within organisations, for example in field texture correlation.

5. What principles should guide consideration of viable and optimal size of soil and land resource survey units (organization not just field team size)?

The optimal size of survey organisations should depend on the rate of land use change within each State and hence the demand for surveys and land capability assessment. Nevertheless there was consensus that organisations should be sufficiently large to develop expertise thereby facilitating in-service training and to have an effective influence on users of survey/capability assessments. It was also felt desirable that survey organisations should include back-up service groups for functions such as laboratory analysis, computing and drafting.

Survey team size and composition was thought to be dependent on the objectives and type of survey required, however, land capability assessment requires a multi-disciplinary approach involving the user at appropriate stages. Most organisations felt that to allow large survey projects to proceed, there was the need to develop a
specialist team of experienced staff who could handle day to day requests for information and short term surveys/assessments.

Overall the Workshop felt that there was a pressing need to examine progress with soil and land survey on a national basis and thus highlight where needs are not being met.
Theme 4. Evaluating the information base

B.E. Vandersee
Department of Primary Industries, Qld.

Methods used to describe and evaluate land resources vary considerably not only between Australian States but throughout the world.

Initially resource surveys concentrated on the characterisation of the resources (soils, landform, vegetation, etc.) with a minimum of input on the interpretation of this data in terms of land use options. Subsequent to this, more emphasis has been placed on the interpretative side i.e. land capability - land suitability.

Regardless of the land classification system being used it should be such that it is

- Capable of clear definition in order that it might be applied with reasonable consistency by different people in different parts of the State or Nation.
- Suitable for use in National, State or local surveys.
- Readily understandable by planners and other persons not necessarily expert in agricultural matters.
- As objective and uncomplicated as practicable.

I support the above objectives (after Boddington 1978) and believe that the land classification and evaluation data we provide would be more readily accepted and used if these objectives were met.

Definitions

Land capability has been defined in a number of ways however the simplest definition could be 'That it is the ability of land to support a particular type of use without causing permanent damage'...(Austin and Cocks 1978).

In the context of this workshop the term land capability assessment refers to the use of selected physical environmental criteria (such as effective rainfall, slope, soil depth, etc.) to assess the ability of the land to sustain a specified use without producing undesired on-site or off-site effects.

The term land suitability assessment has been used synonymously with land capability in many instances and in Queensland most of our recent land capability assessments can be equated to this definition of land capability. We do not take into account economic social or political factors when determining land suitability. The two terms are synonymous when discussing methodology in Queensland.

Agricultural land capability classification can be for a specific purpose or can be a general purpose scheme attempting to cover a wide
range of uses. In Queensland land capability has closely followed the general purpose system used by the Soil Conservation Service of the U.S.A. (Klingebiel and Montgomery, 1961) while land suitability has tended to be more crop specific. This will be elaborated on later in the paper.

Techniques of land use capability assessment

I propose briefly discussing the systems in use in selected overseas organisations, in various Australian States and then elaborating on the Queensland approaches.

Regardless of the reason for the classification it should be acknowledged that the starting point of any system of land classification must be the soil. As Professor A.P.A. Vink states (1960) "All good classification is based on a good soil classification". I am making the assumption that any organisation that is seriously involved in land capability assessment will ensure that the classification is based on an adequate resource (soil) base.

The Americans executed the first modern scientific soil surveys with the U.S. soil survey being founded in 1898 however it is only in post-war years that the number of surveys and activity in soil survey throughout the world has really increased. Many soil maps were not readily accepted by the end user and this troubled the soil surveyors. The solution has been the production of an interpretative map - that is in addition to the soils map, a map or maps of land suitability or capability is produced. These show the variation in grade of land with reference to one or more land uses and this is the subject of this workshop.

In discussing the methods used in overseas countries I have drawn heavily on the book by Davidson (1980) on Soils and Land Use Planning and would recommend it to you for further reading.

(a) The American Method

The American method of land capability assessment has evolved over the last 39 years with a comprehensive handbook being published in 1961 (Klingebiel and Montgomery). It is important to note that land capability assessment is based on a broader range of characteristics than just soil properties. It utilised information on slope angle, climate, flood and erosion risk, as well as soil properties.

As most of you will be familiar with this system I propose to only broadly outline the concept. The concept can be simply illustrated in Figure 1. There are eight classes and as the degree of limitation increases, so the range of land use options decreases. The USDA method has three levels in its classification structure.

(1) Capability class

The broadest category with a total of eight classes defined and labelled I to VIII.
(ii) Capability subclass

These indicate the type of limitations encountered within the classes e.g. erosional hazard, rooting zone restrictions and problems of climate, stoniness, low fertility, salinity or wetness are indicated by subscript.

(iii) Capability unit

This is a subdivision of the subclass. Land in one capability unit clearly includes many different soils but has little variation in degree and type of limitation to land use but in addition is suitable for similar crops under similar farm and soil management schemes. The type of land in each of the eight capability classes was fully described by Klingebiel and Montgomery (1961).

A major criticism of this system is a distinct lack of quantitative criteria in the description of the capability classes. Phrases such as 'gentle slopes', 'moderate susceptibility to wind or water erosion' or 'less than ideal soil depth' clearly lack precision of definition and make them liable to diversity of interpretation. On the other hand one of the strengths of the system is claimed to be its flexibility as it can be used across a range of environments. It is argued by Davidson (1980) that the method would be better described as a framework for land capability assessment since it can be adopted for a wide variety of environmental conditions.

(b) The Canadian Method

Land capability assessment in Canada was initiated by the Canadian Land Inventory which was established in 1963. The general approach of the Canadian land capability scheme is modelled on the USDA method, though there are some important differences. The scheme has a method of soil capability classification for agriculture as well as separate schemes for forestry, recreation and wildlife. All the Canadian schemes have seven classes in contrast to the eight of the USDA method. The soil capability classes may be summarised as follows.

Class 1 - Soils in this class have no significant limitations to use for crops.

Class 2 - Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.

Class 3 - Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices.
Class 4 - Soils in this class have severe limitations that restrict the range of crops or require special conservation practices or both.

Class 5 - Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, and improvement practices are feasible.

Class 6 - Soils in this class are capable only of producing perennial forage crops and improvement practices are not feasible.

Class 7 - Soils in this class have no capability for arable culture or permanent pasture.

0 - Organic soils - not placed in a capability class.

The Canadian system indicates subclasses by letter but has a wider range of limitations then the USDA method. As many of the underlying assumptions in the Canadian scheme are similar to the USDA scheme similar problems arise i.e. poor definition of criteria, lack of consistency in interpretation.

(c) The British Method

Despite earlier, agricultural land classification schemes it was not until the 1960's that a Land Use Capability Classification modelled on the USDA scheme was developed for Britain (Bibby and Mackney 1969). As with the American and Canadian schemes a number of assumptions are specified. For example the classification is primarily for agricultural purposes. A moderate to high level of management is assumed. Land is only graded on the basis of limitations which cannot be removed or reduced at acceptable cost. Distance to markets, types of roads and farm structure are not taken into account. Like the Canadian method, the British one has only seven classes. The American subclasses are also used with the addition of subclasses for gradient and soil pattern limitations. A characteristic of the British method is that classes are more precisely defined with actual limiting values being specified for specific properties.

The land use capability classes of the soil survey scheme can be summarised as follows.

Class 1 - Land with very minor or no physical limitations to use.

Class 2 - Land with minor limitations that reduce the choice of crops and interfere with cultivation.

Class 3 - Land with moderate limitations that restrict the choice of crops and/or demand careful management.

Class 4 - Land with moderately severe limitations that restrict the choice of crops and/or require very careful management practices.

Class 5 - Land with severe limitations that restrict its use to pasture, forestry or recreation.
Class 6 - Land with very severe limitations that restrict its use to rough grazing, forestry and recreation.

Class 7 - Land with extremely severe limitations that cannot be rectified.

Despite the inclusion of critical values for specific limitations problems were often encountered in assigning sites to specific land capability classes. As a result a land judging form was produced to ensure that all limitations were assessed at any one site.

(d) The New Zealand and Australian Methods

As is the case for Britain and Canada the land capability schemes adopted in New Zealand and Australia were largely based on the Klingebiel and Montgomery method (1961).

In Queensland the eight class system was modified slightly (Rosser et al. 1974) however there are still three primary divisions based on the degree of limitation to use for agricultural purposes. The eight classes are allotted to the three divisions on the following basis.

Division A - Agricultural land, arable Classes I - IV
Division B - Agricultural land, pastoral Classes V - VII
Division C - Non agricultural land Class VIII

The eight classes show the degree of limitation to land use but not the type of limitation. A system of 14 limitations embraced in three groups are used for this.

They are:

• Factors which control productivity or choice of crops such as moisture availability, soil nutrient status or salinity and sodicity.

• Factors which limit the use of agricultural machinery such as topography, stoniness or wetness.

• Factors which control land degradation such as susceptibility to water erosion, wind erosion and flooding.

Other States adopted similar systems to varying degrees.

In more recent years there has been an increasing need to determine the capability/suitability of land for specific purposes e.g. dryland cropping, urban, recreation, irrigation, and in some cases this is extending to classifications of capability/suitability for particular crops or groups of crops or specific single uses.
Most Australian States have now developed land capability/suitability classifications based on a five (5) class system. These systems vary from the five classes used for rapid assessment of rural lands for overall planning purposes and therefore identifying land worthy of being retained for agriculture (Riddler 1983) to the five class system used for specific individual crops or uses (Rowe et al. 1981, Holz and Shields 1984 (in prep.), Smith and Capelin 1984, Capelin 1979 and Holz 1979).

The five class system of agricultural capability/suitability very broadly describes classes 1 to 3 as land suited to a wide variety of agricultural production. Class 1 and some of class 2, lands are suited to intensive agriculture, including horticultural crops and row crops. The use of class 1 lands is limited only by the farmers means and management. Class 2 lands have a number of constraints to continual long term production such as climate, limited area and various soil constraints.

Class 3 land includes lands which may be used for occasional cash crops or fodder crops within a pasture rotation system. Where physical constraints are present, class 3 grazing lands are capable of moderate to high levels of pasture production, based either on introduced species or native pastures.

Class 4 lands are unsuitable for cultivation but may be improved by a range of management techniques.

Class 5 land is unsuitable for agriculture but may provide seasonally some rough grazing.

This agricultural capability/suitability classification is an interpretative classification based on the effects of climate, topography and soil characteristics as limitations to land use for agriculture and on the general productive capacity for pastures suited to the area. The lands within a particular class are similar with respect to degree but not kind of limitation for agricultural use.

This system appears to be very useful from a regional planning point of view but is limited in its usefulness when considering capability/suitability for specific uses.

I now propose commenting on the Victorian and Queensland systems being used for land capability/suitability assessment for specific crops/uses.

The Victorian system has been described by Howe and Gibbons (1982) and Rowe, Howe and Alley (1981). The system has been developed to provide a system of describing land capability for specific uses including engineering purposes, septic waste disposal, recreation, grazing, cropping and forestry. To develop a land capability rating system for any specific purpose requires people with expertise in the type of land use being considered. It is then necessary to identify those land characteristics or land qualities which have dominant effects on the production and hazards to land and water arising from the type of land use being considered.
The Victorian system for land capability for cropping has five classes with the severity of limitation increasing from class 1 to class 5. The five classes are presented in Table 1.

To determine a land capability class of a particular piece of land requires an assessment of the limitations present and assessing the effect of these limitations on the performance of the land. This is done in the form of a rating table with, on the one axis, a list of the relevant criteria or land characteristics and on the other axis, the values or class limits for each land characteristic corresponding to the five classes of limitation (Table 2).

Wherever possible quantification of all values used in the assessment should be attempted. The greater the proportion of values quantified the more likely the capability class will withstand the test of time.

It would appear that the Victorian system has not yet developed to determining capability for specific crops although the system could readily accommodate such a scheme.

In Queensland a similar five class system is used to determine suitability (capability) primarily for specific crops although it is commonly used to define valuable agricultural land.

Broadly defined, classes 1, 2 and 3 are suitable for the particular use or crop in question, class 4 is marginal and class 5 is unsuitable.

Briefly the classes can be defined as:

Class 1 - Land suitable for the long term production of crops with no or few limitations.
Class 2 - Land suitable for the long term production of crops but having slight limitations to use.
Class 3 - Land suitable for the long term production of crops but having moderate limitations to use.
Class 4 - Land marginally suitable for long term crop production with severe limitations to use.
Class 5 - Land which is not suitable for the long term production of crops.

Within the definition, the word crop is frequently changed for the particular crop use in question e.g. sugar cane, horticulture tree crops, rice, etc.

The Queensland system is not unlike the Victorian system. In developing the classification for a particular crop for a particular district it is necessary to define the limitations operating in that area and to determine the degree to which these limitations affect the use of that land. The limiting factors operating should be able to be determined directly or inferred from field or laboratory measurements (Smith and Capelin 1984). The rating table described for Victoria has not been developed here however once the limiting factors are determined they are assessed for each site or unit being evaluated.
Table 1  Land capability classes (Howe and Gibbons 1982)

<table>
<thead>
<tr>
<th>Class</th>
<th>Degree of Limitation to Development</th>
<th>General Description and Management Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nil to very low</td>
<td>Standard designs and installation techniques, normal site preparation and management should be satisfactory to minimize the impact on the environment.</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>Careful planning and the use of standard specifications for site preparation, construction and follow-up management should minimize development impact on the land.</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Specialised designs and installation techniques are required to minimize development impact on the environment.</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
<td>Extensively modified design and installation techniques, exceptionally careful site preparation and management are necessary to minimize the impact on the environment. Referral to a specialist authority for advice is strongly recommended.</td>
</tr>
<tr>
<td>5</td>
<td>Severe</td>
<td>Severe deterioration of the environment will probably occur if attempted in these areas.</td>
</tr>
</tbody>
</table>
TABLE 2. LAND CAPABILITY RATING FOR INTENSIVE CROPPING (HOWE AND GIBBONS 1982)

<table>
<thead>
<tr>
<th>LAND FEATURES AFFECTING USE</th>
<th>CAPABILITY CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>SOIL STRUCTURE</td>
<td></td>
</tr>
<tr>
<td>GRADIENT</td>
<td></td>
</tr>
<tr>
<td>Apedal-weak</td>
<td>0-4%</td>
</tr>
<tr>
<td>Moderate, S.G.</td>
<td>0-8%</td>
</tr>
<tr>
<td>Strong</td>
<td>0-15%</td>
</tr>
<tr>
<td>FLOODING RETURN PERIOD</td>
<td></td>
</tr>
<tr>
<td>More than 20 years</td>
<td>10 years to 5 years</td>
</tr>
<tr>
<td>SOIL DRAINAGE CLASS</td>
<td></td>
</tr>
<tr>
<td>Well drained,</td>
<td></td>
</tr>
<tr>
<td>Moderately well drained</td>
<td></td>
</tr>
<tr>
<td>Excessively well drained</td>
<td></td>
</tr>
<tr>
<td>Imperfectly drained</td>
<td></td>
</tr>
<tr>
<td>Poorly drained</td>
<td></td>
</tr>
<tr>
<td>Very poorly drained</td>
<td></td>
</tr>
<tr>
<td>ROOTING DEPTH</td>
<td></td>
</tr>
<tr>
<td>More than 50cm</td>
<td>30cm to 20cm</td>
</tr>
<tr>
<td>TEXTURE OF A HORIZON</td>
<td>L,SL,CL</td>
</tr>
<tr>
<td>AGGREGATE STABILITY OF A HORIZON</td>
<td>1 (stable)</td>
</tr>
<tr>
<td>GRAVELS &amp; STONES</td>
<td></td>
</tr>
<tr>
<td>Less than 4%</td>
<td>4% to 10%</td>
</tr>
<tr>
<td>BOULDERS &amp; ROCK OUTCROP</td>
<td>Less than 0.01%</td>
</tr>
</tbody>
</table>
The more recent studies have initially defined a soils base (1:100 000 or larger) and subsequently a land suitability/capability map has been prepared. The system is computerised so that data may be retrieved at any time. All data is stored relevant to Unique Map Areas U.M.A. (i.e. a single map occurrence of the attribute mapped on the base map - soil unit). For each U.M.A. data is stored in relation to its location, and basic soil or resource characteristics and the previously determined limitations are evaluated to determine their degree of limitation in this U.M.A. The data file is then used to prepare the land suitability map by indicating which U.M.A.'s should be grouped into a particular class. The actual limitations are not shown on the face of the map but can be readily determined for all or particular U.M.A.'s by accessing the data file. The benefit of this system is that the computer can be used to quickly develop overlay maps indicating U.M.A.'s with similar limitations, similar degree of limitations, etc. The aim of the system is to develop it to the stage where specific thematic maps can be produced from the data file for specific purposes i.e. a map of all U.M.A.'s with waterlogging hazard and yellow podzolic soil and in class 4.

Like the other schemes in existence it depends considerably on interpretative or subjective assessment. Smith and Capelin (1984) presented techniques for attempting to make more quantified or objective determinations of suitability/capability.

Identification of key criteria relevant to dryland cropping

As suggested earlier the key criteria for the particular site or area in question should be determined as part of that study. It is important to have an overall check list of factors which should be considered before selecting those relevant to the area in question. The Victorian system lists gradient, flooding, soil drainage class, rooting depth, texture of A horizon, aggregate stability of A horizon, gravels and stones and boulders and rock outcrops. In Queensland we usually start with a list which includes climate, moisture availability, effective soil depth, soil physical factors, soil nutrient fertility, soil salinity or sodicity, topography, soil workability, rockiness or stoniness, microrelief, wetness, susceptibility to water erosion, susceptibility to flooding and susceptibility to wind erosion. From this list those relevant to the area of study are selected and evaluated. Often it is only a specific factor within the major factors which is limiting e.g. phosphorus levels as part of soil fertility. These factors become extremely important when particular crops are sensitive to or have specific requirements in relation to the above factors.

The key question then is how to evaluate each of the selected factors particularly in relation to the effect each has on the performance of the land for the use in question. It is relatively easy to characterise the resource unit (U.M.A.) in terms of its physical, chemical and biological aspects however it is more difficult to rate or classify the resource unit (U.M.A.) in terms of its suitability for a particular crop or group of crops. To do this effectively requires an understanding of the plants requirements so that these may be evaluated in relation to the resource units characteristics. Although a significant amount of data of this nature is known it is not generally in a readily accessible format. Hackett and Caralone (1982) have compiled plant information in a form able to be used for this purpose. For 150 edible horticultural...
crops they have defined attributes in relation to climate, nutrition, soil and landform and pest and disease management and husbandry. This comprehensive plant tolerance data is valuable for horticulture crops and a similar data bank for other crops would seem desirable.

Every effort should be made to quantify as much of the data evaluation as possible and remove the subjectivity which exists in many areas. The level to which quantification can be achieved and precision obtained in the classification system is uncertain. It is argued by some people that the capability rating should go no further than a suitable or unsuitable rating. I don't support this approach although I believe there certainly needs to be a limit to the number of classes.

In Queensland we do use the five class system however for broad planning purposes we use a three class system.

A  Classes 1, 2 and 3 combined  - Suitable
B  Class 4  - Marginal
C  Class 5  - Unsuitable

This simplified system is readily accepted by planners on a regional basis and appears to work effectively.

Within the five class system I believe the classes 1 to 3 allow for the presentation of the degree of severity of the limitations operating thus indicating increasing inputs in relation to management. Class 4 - the marginal class - allows a conservative approach where doubt exists without excluding the land completely. Obviously with intensive management practices or the development of new technology, crops, etc. this land may be reclassified as suitable.

Some concerns have been raised with the five class system which may be worth noting.

It is claimed by some people that in a five class system it is difficult to convince planners that class 2 or class 3 land is not referring to second rate and third rate land. In actual fact these lands could be as productive or more productive than class 1 lands providing the appropriate management needs, as expressed by the limitations, are addressed. I see this rather as an educational need for the users than a fault with the system although in Queensland we do use the three class suitable, marginal and unsuitable system, as indicated earlier, for regional planning purposes.

Another problem with the system is that there is often a tendency to assign intergrade classes to particular resource units i.e. class 2-3, etc. This problem can be avoided by ensuring that the classification is based on a sound resource base. Where a sound resource base does not exist or does not form part of the overall classification there is more likelihood that the intergrades will be used. Obviously this creates further uncertainty for the user and in reality is converting a five class system to a six or more class system. I don't believe that intergrades are justified when suitability is being assessed for individual crops or uses and would recommend avoiding such categories wherever possible.
Model based approaches

My original title and briefing notes suggested comment about model based approaches was required. I don't propose spending much time on this aspect and this topic may be worth discussing in the group sessions.

Certainly research on simulation models for biological systems is developing and considerable progress is being made. Modelling is unlikely to be extremely useful for determining land capability/suitability until the interactions between genotype and the environment can be predicted and when an accurate prediction of how the land factors that determine crop performance co-vary with the parameters used in the definition of the resource units can be made.

No doubt modelling can be used to establish the relative value or performance of particular parcels of land however I suggest that it is unlikely that modelling will be able to be used to quantify the productive capacity. It is an extremely complex system, complicated by environment, plant genotype and land resource and management inputs. The best that could be expected is a rating of the relative performance or value of particular parcels of land which is what we are currently doing either manually or through the computer in our present evaluations of land capability.

The modelling approach may prove a useful technique of monitoring the performance of the present classifications. At present most schemes are monitored through evaluation of the observable or measured performance of crops or uses over time or comparisons with performance in other similar situations. The classification system presently depends fairly heavily on subjectivity for the final decision hence practical experience plays an important role in establishing the key criteria in the classification as well as in the final evaluation.

Summary comments

There are a range of techniques used for assessing land capability/suitability throughout the world.

The systems were originally based very largely of the eight class USDA system of Klingebiel and Montgomery (1961).

More recent systems, the five class systems, primarily evaluate the classes I to IV of USDA system.

Systems vary throughout Australia although there is a common theme within these systems i.e. class I has few or no limitations to class 5 with severe limitations to use.

Each unit identified as a particular class in a specific study has a similar severity of limitation operating although not necessarily the same limitations.

All systems still contain a certain amount of subjective assessment.
Quantification of factors is essential to allow for a more objective
assessment to be made.

The classification system is only as good as the resource base used.
The better or more detailed the resource information the more precise
the classification will be.

Model based approaches appear desirable but are not as yet effective in
this area.

Monitoring of the classification is seldom formally conducted. The
evaluation is most likely to be related to performance of a particular
crop under the management system used at that time.

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Theme 4: Topics Raised and Summary of Discussion

Topics For Syndicate Discussion:

1. Value of the five class system versus the three class system.
2. General dryland crop suitability versus specific crop or crop group suitability.
4. Value of modelling in determining classes, class limits or performance in particular classes.
5. Techniques for monitoring the performance of the system once established and in use.
6. Problems with class 3 land being considered third rate land.

Summary Plenary Reporting Discussion:

Consensus seems to be:

A. The need to collect site specific information and collate on a U.M.A. or appropriate geographical unit basis (the smallest unit identified during the study) either manually or preferably through computerisation to provide a comprehensive resource base.

B. This resource base can then be interpreted for the particular client's demands/purposes using a 3, 5 or 8 class system. The comprehensive resource base enables re-interpretation to cater for changes in technology, crops, uses or new data on specific requirements for specific crops (currently fairly limited). Any system should be monitored to assess performance over time.

C. The use of a modelling approach in land capability assessment is virtually untried but it was felt that process models may be of use if a large amount of crop productivity and climatic data is available.

D. Interpretation must be carried out by people familiar with the resources, preferably the provider or collector of the data and users/clients must be educated in the use of data and the limitations of the data provided. Provision of potential land capability ratings, e.g. class 3 land, capable of sustained production provided certain limitations are overcome, is a way of overcoming class 3 land being considered third rate or marginal land.
Theme 5. Effective methods of communicating the results of land capability assessment to various users.

Part A. The information provider's viewpoint

D F. Howe
Land Protection Service
Department of Conservation Forests & Lands, Vic.

Introduction

The approach to Land Capability Assessment outlined in this paper has been influenced by a number of factors, some quite subtle, which are not always stated but which nevertheless must be recognised.

The factors are:

1. Institutional bias: The land capability information discussed here emanates from the Land Protection Service, (formerly Soil Conservation Authority) an organization primarily concerned with controlling land degradation. The land degradation brief narrows the focus of the information compared with output from an organization which might have a productivity based brief.

2. The range of clients currently being serviced is somewhat narrow, being primarily land use planners at the State and local Government levels. The specialised needs of this group has introduced bias into the output information which, while satisfying the particular needs of the present users, might not meet the specialised requirements of, for example, an agronomist interested in a specific crop.

3. A major restriction on the generation of land capability data has been the limited staff resources available. The existing operational environment has led to the adoption of techniques which attempt to maximise output per unit effort and which rely upon first approximations to stratify study areas so that detailed investigations are carried out only where they are needed.

While some land capability information has been generated for assessing dryland annual cropping, the bulk of work to date has concentrated on providing base data for local Government land use planning. Prime focus has been on erosion risk mapping and water supply catchment protection.

Basic Concepts

Land capability is defined as a measure of the ability of land to sustain a particular form of land use without degrading the land resource. As referred to in this paper, it is restricted to being determined by physical land characteristics as distinct from land
suitability which results from the interaction of land capability with social and economic factors. Land capability is presumed to be an intrinsic property of land while land suitability is less fixed in time, being subject to the vagaries of market forces including fluctuations in interest rates.

Four variables determine land capability. They are:

1. the land resource
2. the kind and level of inputs
3. the kind and level of outputs
4. the risk of land degradation

The obviously complex relationship between these variables can be simplified. If, for a given form of output, (that is, the land use objective is fixed), an assumption is made regarding the inputs (such as available skills and technology), then what remains is the relationship between the physical land attributes and the level of hazard or risk of land degradation (which can also be expressed as a level of limitation).

Obviously, land capability will vary with different levels of management and it is usually assumed that "average" or else "sub-optimal" management is adopted. In general, a lower level of land capability, (that is, a higher level of limitation) necessitates a higher plane of inputs, (management) if the risk of degradation is to be held constant.

For fairly well defined land uses, such as dryland annual cropping, land capability can be readily determined which links land type to risk of degradation. Land capability information can be used for a range of applications such as determining land for optimal production, identifying hazardous land for developing soil conservation programs and for targeting areas in need of extension programs to encourage the adoption of appropriate forms of land management.

Method

Two stages are involved. Firstly, a Land Inventory is developed which describes soils, landforms and degradation potential at an appropriate level of resolution. Secondly, Interpretations are made of the physical attributes of the land types which have been identified and delineated.

The land inventory stage currently relies upon aerial photographic interpretation and ground sampling and interpretations are made using criteria which combine the USDA Soil Survey Interpretations, FAO guidelines and local modifications. For each land use there are 5 classes of land capability and 19 possible sub-classes to identify specific limitations. Definitions of the capability classes are given in Table 1. Sub-classes used to indicate limitations appear in Table 2.

Certain key clients are provided with land capability information on the understanding that feedback is required so that they can assist in further development of the method. This approach increases the opportunities for testing interim results.
The rationale behind retaining separate Inventory and Interpretation stages in the method is to facilitate re-interpretation of the basic land resource data should the assessment criteria alter as a result of advances in technology for a particular land use. The availability of a separate land resource inventory also has an advantage in being available for interpretation for land uses which may not have been foreseen at the time of initial data acquisition.

Costs associated with providing land capability information at a scale of 1:25,000 lie in the range $60 to $120 per sq.km and a unit team is able to work at a rate of 0.7 man days per sq.km (1000 sq.km/year).

Output

Land Capability information can be presented either in the form of a standard product or else it can be packaged so as to be client-specific. The standard product may be easier to produce but will rarely be as effective as specific data produced to meet the requirements of a given client.

Efficiency in producing land capability information can be arrived at by developing a standardized framework and set of guidelines from which “modules” of information can be drawn which are appropriate to a user’s needs. The key to success here lies in accurately determining just what the client’s needs are before undertaking a land capability assessment.

Observations from the Provider’s View Point

With the clarity of hindsight it is possible to pass judgement on a considerable number of early land capability studies undertaken by this and other organizations.

In general, until relatively recent times, only minimal feedback came from target clients. This could be due to the possibility that either (i) the information was perfect and clearly stated or else, (ii) the information was not understood or not thoroughly used. A common assumption appears to have been that the users were entirely capable of understanding all the highly technical data presented to them. This is not always the case.

A major stimulus to the development of current land capability assessment methods has been the attempt to maximise the value of information to the client. Just how much of an improvement has been achieved and how much potential for improvement remains is unclear. There is certainly more feedback now.

While the actual needs of the client can be very diverse, essentially what is usually requested is a simplification of complex land and soils data to arrive at a yes/no decision to guide land use. With some perseverance, a land capability assessor should be able to have the validity of a third category accepted by the client, a category which accommodates a “may be” class, at least. At the other extreme, a pedologist may recognize in excess of forty to eighty different classes of soils or land types, so clearly it must be recognized that there is ground for compromise. The compromise is determined by the needs which the information has to satisfy.
### TABLE 1. LAND CAPABILITY RATING CLASSES

<table>
<thead>
<tr>
<th>Capability Class</th>
<th>Degree of Limitation to Development</th>
<th>General Description and Management Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Very good)</td>
<td>The limitations of long term instability, engineering difficulties or erosion hazard do not occur or they are very slight.</td>
<td>Areas with high capability for the proposed use. Standard designs and installation techniques, normal site preparation and management should be satisfactory to minimise the impact on the environment.</td>
</tr>
<tr>
<td>2 (Good)</td>
<td>Slight limitations are present in the form of engineering difficulties and/or erosion hazard.</td>
<td>Areas capable of being used for the proposed use. Careful planning and the use of standard specifications for site preparation, construction and follow-up management should minimise developmental impact on the land.</td>
</tr>
<tr>
<td>3 (Fair)</td>
<td>Moderate engineering difficulties and/or moderately high erosion hazard exist during construction.</td>
<td>Areas with fair capability for the proposed use. Specialised designs and techniques are required to minimise development impact on the environment.</td>
</tr>
<tr>
<td>4 (Poor)</td>
<td>Considerable engineering difficulties during development and/or a high erosion hazard exists during and after construction.</td>
<td>Areas with poor capability for the proposed use. Extensively modified design and installation techniques, exceptionally careful site preparation and management are necessary to minimise the impact on the environment.</td>
</tr>
<tr>
<td>5 (Very poor)</td>
<td>Long term, severe instability, erosion hazards or engineering difficulties which cannot be practically overcome with current technology.</td>
<td>Areas with very poor capability for the proposed use. Severe deterioration of the environment will probably occur if development is attempted in these areas.</td>
</tr>
</tbody>
</table>

### TABLE 2. SYMBOLS FOR IDENTIFYING SUB-CLASSES

Symbols from the following list are used after the land capability class to identify the nature of the limitations which determine the sub-classes.

<table>
<thead>
<tr>
<th>SOIL CHARACTERISTICS</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>stones and/or gravel</td>
<td>Ss</td>
</tr>
<tr>
<td>Unified soil group</td>
<td>Su</td>
</tr>
<tr>
<td>soil reaction</td>
<td>Sr</td>
</tr>
<tr>
<td>shrink-swell potential</td>
<td>Sl</td>
</tr>
<tr>
<td>dispersible clays</td>
<td>Sd</td>
</tr>
<tr>
<td>soluble salts</td>
<td>Sn</td>
</tr>
<tr>
<td>soil texture</td>
<td>St</td>
</tr>
<tr>
<td>organic matter</td>
<td>So</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEPTH OF MATERIAL</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>depth to hard rock</td>
<td>Dr</td>
</tr>
<tr>
<td>overburden depth</td>
<td>Do</td>
</tr>
<tr>
<td>deposit thickness</td>
<td>Dd</td>
</tr>
<tr>
<td>soil depth</td>
<td>Ds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WETNESS OR DRAINAGE</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>soil profile permeability</td>
<td>Wp</td>
</tr>
<tr>
<td>depth to water table</td>
<td>Wg</td>
</tr>
<tr>
<td>site drainage</td>
<td>Wd</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SLOPE</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LANDSLIP HAZARD</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FLOODING</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>flash floods</td>
<td>Ff</td>
</tr>
<tr>
<td>inundation</td>
<td>Fi</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ROCKINESS</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>rock outcrop</td>
<td>Ro</td>
</tr>
<tr>
<td>boulders</td>
<td>Bd</td>
</tr>
</tbody>
</table>
The basic procedure underlying land capability assessment can be summarized as:

* taking a relatively large number of discrete land types/soils, then
* aggregating the land types or map units into a smaller number of classes by matching the physical attributes of the map units against assessment criteria which are relevant to a specific land use.

The resulting information is best displayed in map form, preferably colour coded, to highlight the location and extent of land with similar capability. The land capability statement is then available to be combined with or overlaid by other relevant data sets to achieve the objectives of the land use planner. Adoption of a conventional "traffic light" coding, with red for "no-go", green for "go" and yellow or orange for caution has proven to be quite useful, gaining some measure of client acceptance.

There are a large number of assumptions that must be made and should be stated in presented data, covering such aspects as presumed level of management, reliability of data, effects of scale changes, need for specialist follow-up, map unit boundary precision and the trade-offs between rapid results and accuracy. In spite of copious warnings and caveats in reports and on maps, there remains ample scope for misunderstanding the information.

Prepared for the possibility of misuse by the client, the Land Capability Assessor should take heed of past errors in the presentation of information and be aware of the distinct possibility that:

1. Information will be wanted within a totally unrealistic time frame,
2. Regardless of how inadequate the data is, the client will consider it to be accurate,
3. Caveats/exclusions/disclaimers will be ignored,
4. Information will be used out of context or else blown-up in scale beyond the limits of usability.

The provider of land capability information, mindful of the foregoing, must achieve a balance between satisfying the demands of users and not out-stripping the credibility of land capability methodology. Resources must be devoted to producing an awareness amongst clientele of the limitations of the information. At the same time, undermining confidence or reducing the credibility of information must be avoided. In an attempt to minimise the risk of misuse of Land Capability Assessment information, the following suggestions are offered:

1. CONSULTATION between user and provider is essential:
   * Before - to determine needs
   * During - to familiarize user with limitations
   * After - to ensure best interpretations
   * Feedback - to improve methods
2. USE OF RESPONSE MAPS to ensure efficient allocation of land capability staff resources. This approach determines where issues are clear cut - such as a very severe erosion risk or perhaps an area where there is no risk at all - and identifies those areas where clearly a far higher level of input is necessary to sort out the "grey" areas of interpretation. The subsequent map determines the level of response in a given area - no action where the issues are clear; automatic referral and follow-up investigation where the map indicates a higher level of complexity.

The referral category can be used to determine priority for detailed land capability studies.

Case Study

Preliminary results of a land capability assessment for dryland annual cropping land within the Melbourne Metropolitan Planning Area appear below in Table 3. The purpose of the exercise was to identify the location and extent of areas capable of supporting cereal cropping so that a quantifiable approach to rationalising competing land use in the area could be developed.

Stages in the study were:

1. Land resource inventory which produced a data base and mapped presentation of land types at 1:25000 scale,

2. Interpretation phase which produced land capability ratings for cereal cropping, grazing, urban development, rural residential subdivision, on-site septic effluent disposal and several soil engineering applications. Table 3 displays the assessment criteria used to evaluate the land resources inventory. Eleven assessment criteria are listed which account for the bulk of variation in the subject land. The class limits for each assessment criterion or parameter, (such as slope), appear across the table and the limits which correspond to a particular class are displayed. To date, the single most limiting feature determines the land capability class, however, work is underway to determine the effect upon land capability of interactions between land features. Clearly, refinement is needed to accommodate such interactions as occur between topsoil texture and slope.
TABLE 3. Land Capability Assessment for Dryland Annual Cropping in the Melbourne Metropolitan Planning Area (Preliminary)

LAND CAPABILITY RATING TABLE

<table>
<thead>
<tr>
<th>CRONING (wheat/barley/oats Rainfall &gt;450mm) 30</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
<th>Class 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE (%)</td>
<td>0-3</td>
<td>3-5</td>
<td>5-8</td>
<td>8-12</td>
<td>12-200</td>
</tr>
<tr>
<td>Drainage</td>
<td>W</td>
<td>MW</td>
<td>I</td>
<td>EW</td>
<td>P</td>
</tr>
<tr>
<td>Flooding</td>
<td>0-5</td>
<td>5-10</td>
<td>10-20</td>
<td>20-100</td>
<td>100-200</td>
</tr>
<tr>
<td>Depth to surface W</td>
<td>500-30</td>
<td>30-25</td>
<td>25-20</td>
<td>20-15</td>
<td>15-0</td>
</tr>
<tr>
<td>Velocity</td>
<td>0-0</td>
<td>0-01</td>
<td>0.01-0.05</td>
<td>0.05-1</td>
<td>1-100</td>
</tr>
<tr>
<td>Rock Outcrop</td>
<td>0-0</td>
<td>0-01</td>
<td>0.01-0.05</td>
<td>0.05-1</td>
<td>1-100</td>
</tr>
<tr>
<td>Topo soil Texture</td>
<td>SL L ORGL LS CL LFS ORGC C LC PSL SCL MC S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth to Hard Rock</td>
<td>500-60</td>
<td>60-50</td>
<td>50-40</td>
<td>40-30</td>
<td>30-0</td>
</tr>
<tr>
<td>Topo soil Depth</td>
<td>500-20</td>
<td>20-10</td>
<td>10-8</td>
<td>8-3</td>
<td>5-0</td>
</tr>
</tbody>
</table>

ASSESSMENT TABLE

<table>
<thead>
<tr>
<th>CAPABILITY RATING FOR</th>
<th>CRONING (wheat/barley/oats Rainfall &gt;450mm) 30</th>
<th>Jan 85</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP UNIT</td>
<td>CLASSIFICATION FOR EACH PARAMETER</td>
<td>OVERALL RATING</td>
</tr>
<tr>
<td>1 G1</td>
<td>1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>2 G1</td>
<td>1 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>3</td>
</tr>
<tr>
<td>3 G2</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>4 G3</td>
<td>1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>5 G3q(f)</td>
<td>1 1 1 1 4 2 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>6 G4</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>7 G5</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>8 G5q(f)</td>
<td>1 1 1 1 4 2 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>9 G5d</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>10 G9</td>
<td>1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>11 G10</td>
<td>1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>5</td>
</tr>
<tr>
<td>12 G11</td>
<td>1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>13 G13</td>
<td>1 2 1 1 3 1 1 1 2 1 1 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>3</td>
</tr>
<tr>
<td>14 G14</td>
<td>1 5 1 1 5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>5</td>
</tr>
<tr>
<td>15 G16</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>1</td>
</tr>
<tr>
<td>16 G1</td>
<td>1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>17 G1I</td>
<td>1 2 1 1 2 1 1 1 2 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>18 G1II</td>
<td>1 2 1 1 1 1 1 1 2 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>19 G1V</td>
<td>1 1 1 1 1 1 1 1 2 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>20 G1VII</td>
<td>1 1 1 1 1 1 1 1 2 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>21 M1</td>
<td>3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>3</td>
</tr>
<tr>
<td>22 M2</td>
<td>3 1 1 1 1 1 1 1 2 1 1 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>3</td>
</tr>
<tr>
<td>23 M3</td>
<td>3 2 1 1 1 1 1 1 2 1 1 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>3</td>
</tr>
<tr>
<td>24 M3q(f)</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>25 M5q(f)</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>26 M5q(f)</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>27 M5q(f)</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>28 M5q</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>29 M5q</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>30 M5q</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>31 M5q</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
<tr>
<td>32 M5q</td>
<td>3 1 1 1 4 2 1 1 2 1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td>4</td>
</tr>
</tbody>
</table>
Below the land capability rating table is a print-out of the assessment. The left hand column indicates the MAP UNIT which corresponds to land type. The right hand column, OVERALL RATING, indicates the most limiting class for each map unit. Access through the body of the table allows the sub-class to be identified. The limitation identified through the sub-class can be used to determine the appropriate form of management required in a particular map unit. As an obvious example, in classes 2, 3 and 4, a soil drainage limitation would require attention to water disposal. A class 5 soil drainage limitation may be too severe to be practically overcome.

In summary, the land capability information lends itself to a range of applications. It can be used to locate and delineate "prime" land. At the other extreme, highly hazardous areas can be identified to either proscribe use or else target areas for community intervention. In the middle ranges of land capability it is possible to assist in determining appropriate management as back-up data for rural extension programs.

References


Theme 5.  Effective methods of communicating the results of land capability assessment to various users.

Part B. The information user's viewpoint

R G. Woodward
N.S.W. Department of Environment and Planning

Introduction

The land assessment techniques developed over the last 50 years have generally been well documented, yet there is a dearth of information on how they have been applied to help solve problems confronted by land planners. There may have been many reasons for this neglect, but it possibly stemmed from the desire to satisfy the demand for urban or agricultural development with little regard to match the requirements of the use to the qualities of the land. The whole sphere of measuring, organising and communicating information to match land uses and land is undergoing rapid evolution as a result of increased data availability and an increasing concern for environmental degradation and protection of non-renewable resources.

Agricultural capability assessment is the procedure or product of evaluating an area of land for its ability to sustain agricultural production given certain economic and technological conditions.

The terms of reference of the assessment usually determine the methods and assumptions of the assessment. Agricultural land assessment may be conducted with respect to surface stability constraints to farming, productivity, economic viability, or overall suitability. Each approach requires successively greater quantities and diversity of data. Assessment schemes have been adapted to local environments, resources and problems, and the need to produce our own scheme for N.S.W. incorporating the best from others become evident.

Agricultural Land Assessment and Land Use Planning

Most assessment schemes in use have been developed in response to a demand for sound resource information for making decisions on land management or planning. Although some schemes have been used more successfully than others, this may be a reflection of the strengths and priorities of government planning legislation or policies, rather than a reflection on the usefulness of the scheme for aiding decision making.

Protection, preservation or conservation of agricultural land may be accomplished by various methods including zoning, the less formal formation of agricultural districts, or by economic incentives such as tax advantages (income, capital gains, inheritance), deferred payments, tax relief, or the purchase of development rights. However, such concessions should not always be interpreted as the means for protecting agricultural land.
In Australia, land use zoning is commonly used to control rural and urban development, although examples exist where other means are used to control agricultural development.

In N.S.W., policies to preserve certain mapped areas of land for agricultural use have been adopted in the draft Illawarra Regional Environmental Plan, the Hunter Regional Plan and the Gosford-Wyong Planning Study. The Valuer-General has agreed to take notice of such zonings when determining the value of land for rate and tax purposes.

At the local government level, many councils over the last 3 years have requested the Department of Agriculture to carry out land capability studies of whole Shires in order to protect the best agricultural land or in order to locate rural residential developments in appropriate areas.

The Minister for Planning and Environment has recently directed that a State Environmental Planning Policy be prepared to control rural residential land use throughout N.S.W. It is expected the Policy will (among other objectives) direct such development away from prime agricultural land and onto land of lower quality.

In conjunction with such policies land capability assessment techniques have been developed to identify the classes of land described in the policies.

The technique used in N.S.W. is described in the accompanying literature "Agricultural Quality - A First Approximation". The user requirements of the procedure finally developed are outlined below.

An Agricultural Assessment Scheme for New South Wales

From the documented experience of people using assessment schemes developed overseas, and the assessment exercises carried out by the Department of Environment and Planning, a number of criteria were established upon which agricultural assessment for planning purposes should be based. These are:

(i) The objectives of the land assessment must be stated clearly so that the technique used and the presentation of the result will achieve the objectives.

(ii) The assessment should be done for a specific purpose, and it should not attempt to satisfy too many purposes or be used for purposes for which it was not designed.

(iii) The assessment technique should be capable of being readily and quickly applied at various scales so that it can be used uniformly and comparably for State, regional or local planning.

(iv) The assessment should ideally be based on objective, quantitative data rather than on skill or judgement.

(v) The assumptions adopted in the assessment should be clearly defined so that they can be accounted for when applying the
results, modifying or improving the technique, or for comparison with other assessments or with other areas.

(vi) The assessment should be presented in an uncomplicated format that facilitates its integration into planning and is readily understandable to people without specialised knowledge.

(vii) The assessment should incorporate bio-physical and socio-economic data into a single measure of suitability.

(viii) The reliability or weakness of the assessment should be explained and problems likely to arise in interpretation should be anticipated and highlighted.

Application

The N.S.W. agricultural assessment scheme has been in use for some 3 years. It is being progressively applied by the Department of Agriculture at the request of local government to eventually cover all the priority planning areas in the eastern and central parts of the State.

Only recently have the problems which were envisaged in integrating the product into local environmental plans arisen.

As in many decisions concerning natural resources, the provision of technical information is less than half the battle. Community awareness and support, and political will, are the principal factors determining the adoption of recommendations arising from land assessment procedures.
Chapter Nine: Agricultural Quality — A first approximation

9.1 INTRODUCTION

A knowledge of the relative agricultural capability of the land within a local government area will assist a council to:

- develop appropriate policies for land which it may wish to see retained in crop and pasture production;
- identify those areas of land it considers to be more suited to uses such as rural residential and hobby farming than to commercial agriculture.

The identification of lands best suited to crop and pasture production forms the basis for delineation of Rural (a) zones throughout a local government area and the subsequent identification of Rural (b) (small holdings) and Rural (d) (future urban) zones.

Certain types of rural production do not depend on the quality of the land for agriculture and these do not come under this assessment or the resulting recommendations. Such activities include feed lots, pig production in sheds, poultry, nurseries and glasshouses, kennels, and forest crops. Guidelines for the siting and waste management of intensive pig and poultry, nurseries and glasshouses, kennels, and forest crops are available from the State Pollution Control Commission.

9.2 THE METHOD FOR EVALUATING AGRICULTURAL CAPABILITY

A rapid subjective method can be used for estimating the capability of land for production of food and fibre. Expert opinion is sought to rank rural lands into one of five capability classes based on the potential productivity of the land, in the relevant social and economic context. This approach overcomes the need to consider environmental factors in detail and avoids the major problem of collecting and interpreting large quantities of technical data.

The guidelines recommended here for performing the assessment provide a standard system for land classification and ranking which will allow comparisons between lands throughout the State, so that a reasonable estimate of the potential value of the land on a State basis can eventually be obtained.

Land that has a high capability for agriculture may not have a high suitability for agriculture because of adverse demand, cultural or locational factors which make full agricultural use of the land uneconomic or undesirable. These factors can be considered during the implementation phase when zonings are being decided, using the capability data described here and other collected information.

9.3 WHAT IS REQUIRED?

The personnel required will include those officers from the local offices of the Soil Conservation Service and the Department of Agriculture who are specialists in the major agricultural activities of the area and a person (or planner) who is responsible for co-ordinating the exercise and compiling the map.

A suitable base map is essential. For a rural shire this usually is a series of topographic maps at scales of 1:50,000 or 1:100,000. In some cases, topographic maps at a scale of 1:25,000 may be more suitable and can be reduced later if necessary.

Recent aerial photographic coverage, photomaps or orthophotomaps where available, or LANDSAT images of the area under study will also prove useful.

9.4 THE CLASSIFICATION OF AGRICULTURAL LAND

Land can be placed into one of five agricultural capability classes. The essential characteristics of the classes are set out below (and also see Section 9.10):

- Class 1 — Land capable of regular cultivation for cropping, with no constraints to sustained high levels of production. Will include irrigated areas with high production.
- Class 2 — Land suitable for cultivation for cropping, but not suited to continuous cropping or intensive horticulture. Has good capability for agriculture, but where constraints limit the cropping phase to a rotation with improved pastures and thus reduce the overall level of production.
- Class 3 — Land suitable for grazing. Well suited to pasture improvement and can be used, and those that by law or regulation cannot be farmed. Such lands include:
  - slopes greater than 58% (27 degrees) or in notified catchments under the Soil Conservation Act, 1938, slopes greater than 33.5% (18 degrees) where timber clearing or destruction restrictions apply;
  - national parks, nature reserves, other lands reserved under the NP & W Act and State recreation areas;
  - State forests and timber reserves, although sometimes these areas may be suitable and available for grazing.
- Class 4 — Land suitable for grazing and not suited to agriculture are those that are permanently unprofitable to farm, that are very sensitive to disturbance and upon which other activities depend, those that are already committed to other incompatible uses, and those that by law or regulation cannot be farmed.
- Class 5 — Land not suited to agriculture. Agricultural production is very low or zero. Severe or absolute constraints to production imposed by environmental factors.

9.5 LAND THAT NEED NOT BE EVALUATED FOR AGRICULTURE

Lands that can clearly be excluded from agriculture should be identified first in order to reduce the area to be assessed. Lands that should be initially excluded from agriculture are those that are permanently unprofitable to farm, that are very sensitive to disturbance and upon which other activities depend; those that are already committed to other incompatible uses, and those that by law or regulation cannot be farmed. Such lands include:

- slopes greater than 58% (27 degrees) or in notified catchments under the Soil Conservation Act, 1938, slopes greater than 33.5° (18 degrees) where timber clearing or destruction restrictions apply;
- national parks, nature reserves, other lands reserved under the NP & W Act and State recreation areas;
- State forests and timber reserves, although sometimes these areas may be suitable and available for grazing;
- designated foreshores and foreshores of prescribed streams and lakes where land use restrictions apply, and foredunes of beach lands;
- quarries and mining areas, and
- areas zoned urban or village.

These areas are drawn onto the map of the study area. In some cases it will not be necessary to examine the whole local government area, but to confine the study to areas that are under pressure from development and change.

9.6 PREPARING THE AGRICULTURAL CAPABILITY MAP

Agricultural capability measured as potential productivity can be estimated using information on environmental factors or current productivity from well managed areas. As both approaches have advantages and disadvantages, it is suggested that both approaches be used according to the knowledge of the local experts. The compilation of the agricultural quality map involves the following steps:

(i) The topographic base maps:

It may be convenient to assemble the individual topographic maps into one large map. However, the usual practice is to map onto the individual base maps and assemble them at the end of the exercise. Draw in the
boundaries of all lands that need not be evaluated for agriculture. If any parts of the shire are in an irrigation area, then define the boundaries of the irrigation area on the base maps.

(ii) The mapping team.

The team should have the following members:

• the person responsible for co-ordinating the exercise and for compiling the map. This could be a town planner, shire council officer, consultant or an officer of the Department of Agriculture or the Soil Conservation Service;

• the appropriate officers from the local Soil Conservation Service and Department of Agriculture who have expert knowledge of the agricultural activities occurring in the shire. Where unusual agricultural industries are practised, it may be appropriate to confer with the Department of Agriculture officer who is a specialist in the field. However, every attempt should be made to keep the mapping team as small as possible to keep the effort from becoming too burdensome and too costly;

• a driver. It is not necessary for this person to know the area well. The person recording the information (the planner) will be required to navigate at the same time.

(iii) Preliminary work.

Hold a meeting of the mapping team and explain the mapping method. Explain the aims of the assessment by stating what features of the land are to be looked at. In general, the main classes of land to be identified are:

• better quality cropping lands;

• poorer quality cropping lands;

• better quality grazing lands; and

• poorer quality grazing lands.

If feasible, as much as possible of the classification should be done in the office. The different land classes can often be easily identified and the boundaries drawn using the experience of the officers and the information available in the office. The field survey can then concentrate on those areas for which the agricultural officer has less reliable knowledge.

Where one environmental factor is clearly most limiting productivity, then boundaries between the classes may be defined from physical land resource information. These are principally climate, soil type and slope. Slope categories suitable for agricultural assessment are included on the slope map described in Chapter 2.

Where boundaries between agricultural capability classes are based upon the soil type, these boundaries can be established from soil maps if they are at a suitable scale, or from geological maps if the relationship between soil type and geology is readily established. In many instances a soil survey will not be available and a soil survey at the appropriate scale may need to be arranged for specific planning purposes. This can be arranged through the Soil Conservation Service and the Department of Agriculture.

For a local government area climate may determine the highest class of land within the area, and where local variations in climate arise within an area, land capability class may vary as a result.

On many occasions, a more efficient way to establish agricultural capability boundaries is to examine aerial photographs, photomaps and orthophotomaps of the area. Using the stereoscopic (three dimensional) image, an expert in climate or land capability classes should be able to see differences. LANDSAT images available from the Department of Lands often provide a suitable overview of areas under study. These images are available at scales smaller than 1:50,000. They show land use patterns, and in some cases boundaries between land of different capability classes will be apparent.

Boundaries between the classes may also be defined by using a knowledge of the farming systems and estimates of productivity from well managed farms. Such farms may provide a reliable indication of the capability of that particular type of land. Land with similar properties (such as soils, slopes, micro-climate) can then be placed into the same class, although management level may restrict its actual productivity.

The best type of farming system that can be practised in the area will also aid the classification of the land. A knowledge of the system and enterprises used by the better farmers, considered together with the recommendations of the Department’s research and extension officers, will help decide the classification of an area of land.

Every effort should be made to improve the efficiency of field work by thorough preparation and preliminary mapping.

(iv) The field survey.

The survey should concentrate on areas for which little information or first hand knowledge is available. The field mapping team proceeds to drive over the predetermined route. The officer or officer in charge should direct the position of the vehicle and mark any changes in uses or capability which should also be noted (e.g., “productivity is lower on the granite,” “narrow plains,” “poorly drained areas,” “unusual geology,” “hardpan at 30 cm.”) etc. This information may assist in refining the boundaries between areas of land if necessary.

Where possible, parts of the route should cross the ‘grain’ of the terrain, geology or soils so that rapid changes in classes occur which facilitates the placement of boundaries between areas of different capability.

Boundaries which can be quickly and reliably established during the field survey should be marked onto the maps. Otherwise the boundaries are drawn back at the office when other resource information is available (e.g. slope or geological maps). The potential agricultural uses should also be noted on the map for each area and the reasons for any changes in uses or capability should also be noted (e.g., “productivity is lower on the granite,” “narrow plains,” “poorly drained areas,” “unusual geology,” “hardpan at 30 cm.”) etc. This information may assist in refining the boundaries between areas of land if necessary.

The field map should contain land capability ratings. Provisional boundaries between classes, production figures if available, the agricultural uses and comments on those factors which most limit productivity etc. rainfall, shallow soil, slope.

(v) Guidelines.

In order to guide the delineation of land into classes the information in Section 9.10 should be used. Either potential production data, production data from well managed farms or environmental data can be used to help decide into which class an area of land belongs. It is more reliable to use production data than environmental data where more than one environmental factor is the major constraint to high productivity, since the latter interact with each other and it then becomes difficult if not impossible to formulate hard and fast rules for agricultural land use.

Because the environmental factors that influence plant growth interact in complex ways, it is necessary to make some assumptions to properly classify the land. The assumptions on which to base the capability assessment are:

• an adequate or moderately high level of management and technology is used to ensure these are not the limiting factors to productivity (but they may be partially limiting);

• land with constraints that could be economically or legislatively removed should be assessed as if they have been removed, e.g. presence of trees, poor chemical fertility, presence of stones, area or production restrictions;

• land with constraints that have been modified or removed should be assessed on its present status e.g. irrigation areas, flood mitigation areas, cleared land.


9.7 PREPARING A REPORT ON THE AGRICULTURAL CAPABILITY MAP

The test accompanying the map should describe the objectives of the study, the method used, the sources of data, the assumptions underlying the assessment method and any peculiarities concerning the interpretation of the maps.

The text should also describe the agricultural activities in each of the five capability classes and the importance of the land in each class to the agriculture of the local government area. For land in each class, the current type and intensity of agricultural activity, potential or alternative agricultural activity, economic viability and factors influencing it, and the important environmental constraints or cultural factors influencing agricultural activity should be listed. Some estimate should be made of the quantity of production and value of production for each product compared to the whole State, and the contribution of the production to the wellbeing of the shire or region. Likely future trends should also be discussed. A check list of the kinds of variables that may require consideration is given in Section 9.9.

The capability classification together with the social and economic information can then be used as a basis for recommending the quantity and quality of agricultural land that should be zoned for protection against incompatible development and loss of agricultural production.

Where possible the officer from the Department of Agriculture could estimate the relative productivity of each class of land e.g. Class 1 land is two or three times more productive than Class 2 land, etc. These estimates should be included in the report and will help the planner make decisions on the loss of land from agricultural use. These estimates do not have to be highly accurate in order to be useful.

9.8 MAKING THE RECOMMENDATIONS

The recommendations will vary considerably between different areas. They should usually be drawn up on a local government area basis, and work on the principle of protecting the best agricultural land and directing uses incompatible with agriculture onto the lowest quality land first. There are some general principles which may assist in formulating recommendations:

- High quality agricultural land should not be used for incompatible development where land of lower agricultural quality is available and suitable for the purpose;
- Land of Class 1 quality is considered to be of significance to the State and consideration should be given to its protection from incompatible development;
- Land of Class 2 quality is also considered worthy of protection because of its State and regional importance and consideration should be given to its retention in agriculture;
- Areas which are irrigated generally should be recommended for retention in agriculture primarily because of the existing infrastructure (channels, dams, pipes, etc.) and high potential production;
- Class 3 lands should not be alienated from agricultural production if adequate and suitable areas of Classes 4 or 5 land are available. Social and economic factors should be considered when making recommendations in areas of Class 3 or lower quality land which are still operated extensively as full-time farms;
- Consideration should be given to protecting from incompatible development areas which are unique in the State for agricultural activity unless there are strong economic reasons for not doing so. This would include areas which by virtue of their remoteness or special location are under cultivation for foundation seed, bush stock or root stock production, or quarantine zones;
- When recommending rural areas for non-agricultural uses, the particular requirements of the use need to be considered. For rural residential and/or hobby farm uses, it should be noted that the former may require non-productive land preferably with trees (usually falls into Class 5), while the latter may require land with pastures suitable for year-round grazing (land of Class 4 may often be suitable).
- Some forestry enterprises require good quality agricultural land, such as poplar plantations, so that allowance may need to be made to permit such activity on agricultural land.

9.9 CHECKLIST OF FACTORS THAT MAY INFLUENCE AGRICULTURAL ACTIVITY

A list of variables that should be considered when determining the agricultural suitability of land for zoning purposes is presented. Not all these variables may need to be considered in every assessment, and it is NOT necessary to map them or consider them in great detail. Most of this information will form part of the general knowledge of the Department of Agriculture officer involved in the study. Whenever possible, derived measures should be considered, e.g. length of growing season, erosion hazard,
The influence of political decisions and regulations, current or proposed. 

Personal goals, preferences and expectations of farmers, their general education levels, experience and managerial skill. The influence of political decisions and regulations, current or proposed. 

Economic Parameters:
- Present economic context, trends and forecasts for demand, costs and prices.
- Farm income levels, farm costs and returns.
- Availability of local and export markets.
- Present infra-structure, e.g. dairy factories, transport.
- Presence of any comparative advantages.
- Presence of any comparative advantages.
- Economic losses caused by floods are low in the long term.
- Lands are not likely to accumulate excessive salt or develop prolonged high water tables following irrigation.
- Lands are not exposed to recurrent extremes of climate to an extent that productivity is seriously affected.
- Intensive production has been facilitated by existing local or regional infrastructure (such as drainage schemes, irrigation networks or levee banks), except for those parts which have suffered damage beyond economic amelioration.

Class 2
Land suitable for cultivation for cropping, but not suited to continuous cropping or intensive horticulture. It has good capability for agriculture, but where constraints limit the cropping phase to a rotation with improved pastures and thus reduce the overall level of production.

- Class 2 lands can be either (a) or (b):
  (a) where pockets of Class 1 land are too small for general agricultural use and occupy between 25% and 75% inside a zone of a lower class, then that whole zone should be placed in Class 2 provided that the productivity of crops appropriate to that zone is very high, otherwise the zone should be included in Class 3.
  (b) all or nearly all of the following conditions are to be satisfied:
- Land may be level to moderately steep.
- Soils are deep, well to moderately deep, well drained and have good available water capacity.
- Soils have a moderate to high capacity to withstand frequent cultivation and artificial irrigation without serious damage.
- Soil has a moderate to high capability to withstand frequent cultivation and artificial irrigation without serious damage. 
- Soils have a moderate to high capability to withstand frequent cultivation and artificial irrigation without serious damage.
- All, or nearly all, of the following conditions are to be satisfied:
  - Lands are either level or very gently sloping.
  - Soils are deep, well to imperfectly drained, and have good water holding capacity.
  - Soils can be maintained in good tilth and productivity.
  - Erosion damage is nil to slight and potential for future damage is low.
  - Productivity is high to moderately high for a wide range of adapted field crops.
  - The soils have a moderate to high capability to withstand frequent cultivation and artificial irrigation without serious damage.
  - Any adverse soil physical and chemical restraints are capable of economic amelioration.
  - Economic losses caused by floods are low in the long term.

Class 1
Land capable of regular cultivation for cropping (cereals, oilseeds, fodder, etc.) or intensive horticulture (vegetables, orchards). It has a very good capability for agriculture, where there are only minor or no constraints to sustained high levels of production. It includes irrigated areas with high production.

9.10 GUIDELINES FOR CLASSIFYING AGRICULTURAL LAND

Class 1
Land capable of regular cultivation for cropping (cereals, oilseeds, fodder, etc.) or intensive horticulture (vegetables, orchards). It has a very good capability for agriculture, where there are only minor or no constraints to sustained high levels of production. It includes irrigated areas with high production.
Any adverse soil physical and chemical restraints are capable of economic amelioration. Economic losses caused by floods are low in the long term. These are lands where existing local or regional infrastructure (such as drainage schemes, irrigation networks or levee banks) has been provided for intensive production — except for those parts which have suffered damage beyond economic amelioration. Lands are not likely to accumulate excessive salt or develop prolonged high water tables following irrigation.

**Class 3**

Land suitable for grazing — well suited to pasture improvement and can be cultivated for an occasional cash crop or forage crop in conjunction with pasture management. The overall level of production is moderate as a result of high environmental costs which limit the frequency of ground disturbance. Has a moderate capability for agriculture. Pasture land capable of sustained high levels of production, although conservation measures may be required. More than one condition is to be satisfied:

- Lands have either many moderate or few severe limitations of those listed under Class 5, restricting the extent of arable agriculture.
- Sustained high to moderately high levels of productivity of pastures adapted to the region are easily maintained.
- Lands may be very gently to steeply sloping.
- Soils may be deep or shallow, well drained to poorly drained.
- Erosion damage is nil to moderately severe but conservation works are feasible.
- Under artificial irrigation, level lands are incapable of sustained high levels of production, although conservation measures may be required. The overall level of production is moderate as a result of high environmental costs which limit the frequency of ground disturbance. Has a moderate capability for agriculture. Pasture land capable of sustained high levels of production, although conservation measures may be required. More than one condition is to be satisfied:

**Class 4**

Land suitable for grazing and not suitable for cultivation. Agriculture is based on native pastures or improved pastures relying on minimum tillage techniques. The overall level of production is low. Environmental constraints make arable agriculture uneconomic. All or nearly all of the following conditions are to be satisfied:

- Lands are hilly or rolling with steep or moderately steep slopes.
- The degree of stoniness or rockiness is slight to severe but not extreme.
- Erosion damage or hazard is moderate to severe and control works are necessary; severely eroded areas are only capable of economic restoration by the establishment of permanent pasture.
- Soil physical handicaps are sufficiently severe to prevent cultivation but will allow some pasture growth providing year round feed for a low stocking rate.
- While extremes of salinity, salt hazard, toxicity, deficiency, acidity or alkalinity may be present they are not so severe as to prevent plant growth but instead may combine to depress yields seriously and place severe restrictions on the range of suitable pasture species.

Where land is subject to periodic inundation and high water tables, these conditions are generally of short duration.

Where permanent high water tables exist, the land can be drained sufficiently to permit some pasture growth.

The density of bush or scrub may be low to high, but not extremely high.

Where the population of feral and noxious animals is high it does not impose a severe limitation to grazing.

Where the density of weeds is high, successful eradication is only possible by a continuing program.

**Class 5**

Land suited for only rough grazing or land not suited to agriculture. Agricultural production is very low or zero. Severe or absolute constraints to production are imposed by environmental factors. These lands have either a single very severe limitation, or a combination of two or more severe limitations from the following list are present:

- Extremes of — slope; stoniness or rockiness; erosion hazard or damage by wind or water; soil physical handicaps; salinity or salt hazard; surface water or flooding; toxicity or deficiency; acidity or alkalinity; high water tables incapable of economic drainage; or bush or scrub uneconomic to clear.
- Large populations of feral animals inhabit the area.
- High densities of weeds and timber regrowth which are uneconomic to eradicate.
- These are timbered or previously timbered upland areas where clearing has led or may lead to excessive movement of salt into the groundwater.
FIGURE 9.1  Example Map Showing Agricultural Quality

1  CLASS 1 (HIGHEST)
2  CLASS 2
3  CLASS 3
4  CLASS 4
5  CLASS 5 (LOWEST)

DEPARTMENT OF ENVIRONMENT AND PLANNING

COFFS HARBOUR

AGRICULTURAL QUALITY

SCALE 1:50,000
Theme 5: Questions Posed and Responses from Working Groups

1. Should we be assessing hazards separately from productivity?

- Assuming it was desirable, it is difficult to do if the objective is sustained productivity because ignoring hazards will lead to a deterioration of the quantity and quality of the resource which must reduce productivity.

- Depending upon the user and his requirements it may or may not be desirable. Regional land use planners probably prefer both the production and conservation goals embodied in the one input to planning for simplicity. In theory this is how much of the land use planning on a local government area basis works in N.S.W. The Department of Agriculture produces an Agricultural Suitability or Agriculture Quality map which has been produced by multidisciplinary subjective assessment of the land resource following compilation of all existing resource information. Heavy reliance is placed on soils and rural land capability data produced by the Soil Conservation Service of N.S.W.

- Hazard mapping emphasises the negative 'cost to the land' side whilst productivity mapping is more positive. The latter in many cases is desirable so long as the emphasis does not become exploitative.

- The 'pure' limitations approach characterising the USDA based land capability mapping is most beneficial and practical for users concerned with planning and implementing land degradation control and mitigation measures. This is hardly surprising since it was for this purpose that the scheme was developed.

- It is possibly desirable to separate clearly the interpretation of hazard from that of productivity during the survey and in the initial evaluation stage. The mixing of these concepts can be achieved at a later stage should it be considered most appropriate to the user's needs and interpretive ability.

2. What is the relative merits or short comings of 'stand alone' maps versus reports?

Merits of the stand alone maps were fully acknowledged however the users stressed the need for adequate documentation of results and substantiation of evaluation techniques in a follow-up document. Both are therefore required.

Quick effective communication can be achieved providing there is substantial provider/user liaison to express the limitations and assumptions made of the data.

- Must balance expediency of the need with loss of product quality.

- The big danger with stand alone maps is that the necessary disclaimers will in many cases be ignored by the user.
There can be a standard framework for presentation but need not necessarily be in a standard format - the latter can be determined by the needs and interpretive abilities of the users.

'Response maps' were discussed and it was agreed these provided a good means of reducing the amount of ad hoc requests on survey organisations from planners. The three categories are:

1. OK.
2. Automatic referral to survey organisation for comment.
3. No go - hazard risk too high or else agricultural productivity sufficiently high to warrant decision against other land uses.

Generation of response maps for planners required an ability within an organisation to service follow up requests.

3. How can we improve communication?

The short answer is by talking.

The need for greater user/provider liaison before, during and after the survey was emphasised. Pre-survey meetings are needed to ascertain the specific requirements of the user, the appropriate scale and format of data presentation and to advise users of the limitations of the survey and evaluation method. In addition the assumptions made about level of management and how ratings can change in time with technological changes and with changes from one crop to another must be explained.

A number of organisations, for example the N.S.W. Soil Conservation Service and the QLD Department of Primary Industries, appear to have a set interview format prior to survey with clients outside their own organisation. It is suggested that a similar procedure should also be adopted for the 'in house' surveys to clarify objectives.

Increased user involvement during the survey was mentioned as desirable since soil/land resource surveyors are not necessarily expert on the particular land use being considered. Their expertise lies in being able to classify and map soils in a meaningful way for a user and in locating boundaries of land type change with minimum cost and effort. In order to make the best evaluation of land resources for a defined use, the relevant 'land use experts' such as agronomists must be involved. The need for a multidisciplinary approach to land evaluation, involving land use experts, the land resource surveyor and the eventual user was stressed.

With respect to follow-up, one example cited was the Mackay Land Use Advisory Group approach involving the Qld Department of Primary Industries. This did not appear to be too successful although the
reasons were not clear. Qld Department of Primary Industries do however conduct field days with users to acquaint them with soils and their capability.

The topic of having separate survey and interpretive groups was discussed briefly. This was probably the reasoning behind the establishment of the land studies/land capability groups in the Victorian Soil Conservation Authority but due to survey scale requirements and information needs the latter in effect had to become a survey group as well as an interpretive, user orientated one.

It is desirable for the organisation to have the ability to service ad hoc requests, that is the relatively short-time 'fire fighting' studies, and at the same time to conduct regional land resource studies to get ahead of the problems and also to put them in a regional perspective.

If an organisation chooses to do both the fire fighting and the longer term regional research studies by having separate groups, then it is highly desirable that there is a regular interchange of staff between the two groups to enable:

a) researchers to appreciate 'real life' problems

b) front line 'fire fighters' to broaden experience and understand broad landscape processes.

The temptation to split off a resource survey group away from day to day requests from users probably should be resisted as a recurring message regarding better communication is the 'need for users to have direct contact with the land resource surveyors'.

Presentation of results was discussed in the previous question but emphasis here was on having them user orientated rather than in any sort of standard format.

Discussion did not, but perhaps should have addressed the topics of microfiche, dual reports (technical and interpretive) and report format.

Liaison with planners is necessary to help develop a legislative framework for land capability assessment to fit into.

It is interesting to recall in the late 1970's, Beckett and Bie in their study of the effectiveness of soil surveys, recommended that up to 50% of the time available to senior staff of a survey organisation should be spent examining the needs of clients and looking at ways to design surveys to specifically meet those needs.

4. How far should land capability assessment go in land use planning?

Land capability assessment was seen as an initial step in the planning process which should be supplemented with socio-economic data to provide an assessment of land suitability for a particular use.
Ross Woodward outlined the relative contributions of inputs made to a planning decision as follows:

- 30% - land capability data
- 30% - other socio-economic constraints
- 30% - public input following display of draft scheme
- 10% - luck!

In discussions he emphasised that if land resource survey organisations have goals such as protection of prime agricultural land and/or minimisation of land degradation then they must aggressively promote those goals at two stages.

(i) as part of their direct input to planning - it must be simple - as per Figure 9.1 in Dr Woodward's paper - land to be protected clearly outlined rather than a complicated multi-class jigsaw puzzle map. It must be clearly presented because it has to compete for attention against other options and constraints.

(ii) the organisation should consider active promotion within the community of their specific goals in any land use planning matter, as community input, the third 30%, is an important determinant of the end result of planning.

The approach of the N.S.W. Department of Agriculture in the northern coast region was discussed, where that Department went as far as actually drawing up a recommended local government plan for a Shire. Although not yet adopted by the Shire, the approach was fully commended by the N.S.W. Department of Environment and Planning.

General feeling was that all survey organisations recognised the need to go much further towards assisting land use planning clients if their work was going to have any significant effect.

5. Should free market forces determine rural land use?

Very little time remained for discussion of this question. The sole point made was that in effect the free market does determine how land is used on a farm by farm basis. However, if the question was 'should free market forces determine rural land zoning?' then the answer is no. There definitely should be an input here for the benefit of the whole community to ensure that the communities' resource of land is used within its safe capability.
Theme 6. Achieving effective cooperation in the planning, conduct and application of soil and land surveys and of agronomic research

F. R. Gibbons
Land Protection Service, Department of Conservation
Forests and Lands, Vic.

The following points were developed during the course of the Workshop. They are recommended for consideration and adoption by individuals and organisations involved in the planning, conduct and application of soil and land surveys and of agronomic research.

1. There is a need for a total land appraisal system, so as to help in the better use and protection, particularly where major changes in land use are impending, and especially for cropping land.

2. That system should comprise three related but separate parts:
   * land resource survey
   * interpretation of resource data ("land capability assessment")
   * applying the interpretations ("land suitability", planning).

A. With respect to land resource survey:
   a) there is a dearth of data at a detailed scale, and in many areas at a broad scale too;
   b) in those areas without such information and with impending land use change, a programme of land resource surveys at a broad scale should be expedited;
   c) the possible use of existing unco-ordinated data should be examined;
   d) a programme for survey at detailed scale be established, on the basis of the survey at a broad scale, in those areas with anticipated change to intensive land use;
   e) the data-collection should follow that of the Australian Soil and Land Survey Field Handbook, plus climatic data, site-specific and collated on the basis of Unique Mapping Area (UMA), preferably in computer-form;
   f) the feasibility of compatible State data-banks be investigated;
   g) training and awareness of the problem and approach be included in course work up to and including Tertiary level and Community awareness programmes;
   h) quality-control and achievement of technical standards to be facilitated by secondment of staff between States;
1) in any one State, co-ordination of land resource surveys to be provided by a group representing users and providers of land resource information.

B. With respect to land capability assessment:

a) the various States be encouraged to establish or develop a system of interpretation of land data for various land uses, according to client's requirements and including dryland cropping.

b) those systems to have the following features:

   (i) be on the 'limitations' approach, based on the kind and degree of limitation in land-feature or inferred land-quality;

   (ii) be mutually compatible between land uses and States in respect of significance of classes;

   (iii) with 3 or 5 classes; if 5, then similarly grouped to 3;

   (iv) the cause or nature of the limitations to be identified by coded sub-classes;

   (v) be separate for each of the various kinds of land use as required;

   (vi) be preferably with separate indication of:

      * hazards
      * required management
      * feasible production

   (vii) with nominated levels of management for the production and hazard ratings.

c) the limiting factors to the production of the chief crops in various regions and their relationship to performance be identified from existing information on crop phenology and response in a research-proposal to the National Soil Conservation Program;

d) ditto for other land uses co-operatively with people from the industries or Departments involved;

e) the land capability ratings to be linked with the Unique Mapping Area's (UMA) of the land resource survey and prepared on the basis of the characteristics of the UMA;

f) the land surveyors should be involved in establishing the ratings, where feasible.
C. With respect to applying the interpretations:

a) communication should be established at the outset of any project with the client to make and apply the ratings, during the project and in the application of the results;

b) for regional planning purposes, overlays of the various ratings are recommended;

c) for operational planning, sub-classes to be used in preparing and reviewing management prescriptions.

3. A Handbook on Guidelines for Land Capability Assessment, applicable Australia-wide, should be prepared under the auspices of SCSC and ALASC.
## List of Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. Baker</td>
<td>Department of Primary Industries, Indooroopilly, Q.</td>
</tr>
<tr>
<td>J. Beattie</td>
<td>University of Tasmania, Hobart, Tas.</td>
</tr>
<tr>
<td>D. Campbell</td>
<td>Department of Agriculture, Leeton, N.S.W.</td>
</tr>
<tr>
<td>J. Crichton</td>
<td>Department of Agriculture, Parramatta, N.S.W.</td>
</tr>
<tr>
<td>K. Day</td>
<td>Conservation Commission, Darwin, N.T.</td>
</tr>
<tr>
<td>J. Dickenson</td>
<td>Department of Primary Industries, Kingaroy, Q.</td>
</tr>
<tr>
<td>R. French</td>
<td>Department of Agriculture, Adelaide, S.A.</td>
</tr>
<tr>
<td>F. Gibbons</td>
<td>Department of Conservation, Forests &amp; Lands, Kew, Vic.</td>
</tr>
<tr>
<td>B. Griffiths</td>
<td>Conservation and Agriculture, Canberra, A.C.T.</td>
</tr>
<tr>
<td>J. Hindle</td>
<td>Department of Agriculture, N.S.W.</td>
</tr>
<tr>
<td>D. Howe</td>
<td>Department of Conservation, Forests &amp; Land, Kew, Vic.</td>
</tr>
<tr>
<td>R. Junor</td>
<td>Soil Conservation Service of N.S.W., Sydney, N.S.W.</td>
</tr>
<tr>
<td>D. Kent</td>
<td>Department of Primary Industries, Kingaroy, Q.</td>
</tr>
<tr>
<td>R. Lawrie</td>
<td>Department of Agriculture, Parramatta, N.S.W.</td>
</tr>
<tr>
<td>S. Lucas</td>
<td>Conservation Commission, Darwin, N.T.</td>
</tr>
<tr>
<td>S. Macnish</td>
<td>Department of Primary Industries, Bundaberg, Q.</td>
</tr>
<tr>
<td>J. Martin</td>
<td>State Chemical Laboratories, Melbourne, Vic.</td>
</tr>
<tr>
<td>D. MacKenzie</td>
<td>CSIRO, Canberra, A.C.T.</td>
</tr>
<tr>
<td>N. McKenzie</td>
<td>CSIRO, Canberra, A.C.T.</td>
</tr>
<tr>
<td>B. Murphy</td>
<td>Soil Conservation Service of N.S.W., Sydney, N.S.W.</td>
</tr>
<tr>
<td>G. Murtha</td>
<td>CSIRO, Townsville, Q.</td>
</tr>
<tr>
<td>R. Reid</td>
<td>Department of Primary Industries, Kingaroy, Q.</td>
</tr>
<tr>
<td>L. Richley</td>
<td>Department of Agriculture, Hobart, Tas.</td>
</tr>
<tr>
<td>A. Riddler</td>
<td>Department of Agriculture, Parramatta, N.S.W.</td>
</tr>
<tr>
<td>P. Rowland</td>
<td>Department of Primary Industries, Rockhampton, Q.</td>
</tr>
<tr>
<td>G. Scholz</td>
<td>Department of Primary Industries, Roma, Q.</td>
</tr>
<tr>
<td>P. Shields</td>
<td>Department of Primary Industries, Rockhampton, Q.</td>
</tr>
<tr>
<td>B. Salter</td>
<td>Department of Primary Industries, Roma, Q.</td>
</tr>
<tr>
<td>G. Short</td>
<td>Soil Conservation Service of N.S.W., Sydney, N.S.W.</td>
</tr>
<tr>
<td>R. Smith</td>
<td>Department of Agriculture, Wollongbar, N.S.W.</td>
</tr>
<tr>
<td>M. van-Cuylenburg</td>
<td>Conservation Commission, Darwin, N.T.</td>
</tr>
<tr>
<td>B. Vandersee</td>
<td>Department of Primary Industries, Indooroopilly, Q.</td>
</tr>
<tr>
<td>M. Wells</td>
<td>Department of Agriculture, Perth, W.A.</td>
</tr>
<tr>
<td>P. Wilson</td>
<td>Department of Primary Industries, Ingham, Q.</td>
</tr>
<tr>
<td>K. Wetherby</td>
<td>Department of Agriculture, Cleve, S.A.</td>
</tr>
<tr>
<td>R. Woodward</td>
<td>Department of Environment &amp; Planning, Sydney, N.S.W.</td>
</tr>
</tbody>
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ENVIRONMENTAL SOIL MONITORING.
PAPERS PRESENTED AT A SCIENTIFIC WORKSHOP ON
'ENVIRONMENTAL PROTECTION IN THE ALLIGATOR RIVERS REGION N.T.'
MAY, 1983.

P.A. Findlater and J.W. Burgess (Eds.)
December, 1983.

Land Conservation Unit,
Conservation Commission of the N.T.

Technical Memorandum.
CONTENTS

Foreword


P.A. Findlater  - Application of existing data management technology to environmental monitoring of soils in the Alligator Rivers Region Northern Territory.

P.A. Findlater and L.A. White  - Environmental soil monitoring for uranium and copper at Ranger and Nabarlek Alligator Rivers Region Northern Territory.
Foreword

The papers contained in this memorandum were initially produced for a scientific workshop on environmental protection in the Alligator Rivers Region. This workshop, held in May, 1983, was a follow up to workshops that had been held prior to the commencement of uranium mining.

It provided an opportunity for comment and review of the considerable scientific research that has occurred since mining began, and allowed an appraisal of future research priorities.

Workshop papers were invited from all research workers in the region, allowing the presentation of a broad spectrum of research activities. Although biological and hydrological research dominated proceedings, soil research for the region was adequately covered by the material included in this report.

The four papers that follow effectively summarise the history of the A.R.R. environmental soil monitoring programme, since it's conception in the late 1970's. Initially, soil surveys and the collection of two years baseline data was completed, prior to the commencement of mining. In later years, the programme has been restricted to annual soil sampling of selected sites to monitor changes in heavy metal concentrations. The responsibility for this annual sampling and analysis passed from the supervising authority, the Land Conservation Unit, to the mining companies, once the monitoring programme was fully established.

The philosophy and future direction of the soil monitoring programme, it's sampling and analytical methodology, and the data management techniques that have so far been developed are detailed in this memorandum. Future emphasis in the programme is to be directed towards more efficient data management and statistical analysis of both existing data and the annual results.

J.W. Burgess
ENVIRONMENTAL SOIL MONITORING - 
AN OVERVIEW OF ITS PHILOSOPHY AND FUTURE EMPHASIS 
IN THE ALLIGATOR RIVERS REGION N.T. 
1979-1982 
P.A. FINDLATER 
Land Conservation Unit 
Conservation Commission of the N.T. 
Darwin N.T. 

SUMMARY 
The paper presents the general philosophy of environmental monitoring, focusing on the principles for soil monitoring surveillance in the N.T. Uranium Province. In particular the evolution of current principles and practices of the soil monitoring study are discussed. Incorporated in the paper are features of initial problem identification and interpretation of results together with an outline of what future emphasis and direction a soil monitoring programme in the region should undertake. 

INTRODUCTION 
The uranium industry in Australia and particularly in the Alligator Rivers Region of the Northern Territory has come under strong criticism and rigid control. This situation has arisen because of global concern over the disposal of nuclear waste. Also locally in Australia, during the late sixties and throughout the seventies there was a growing public demand for increased environmental protection as a consequence of pollution arising from mining operations such as Rum Jungle in the Northern Territory. 

With the commencement of the Ranger Uranium Mining project in 1970 techniques needed developing to ensure environmental protection. The methods chosen depended on the degree of environmental protection required. The standards of environmental protection required vary widely within the community. For the mining projects in the Alligator Rivers Region the degree of environmental protection required or thought necessary is implied by O'Brien (1973), a federal judicial enquiry (Fox et al. 1976, 1977) and by two workshops held in 1978 and 1979 to develop guidelines for the implementation of environmental policies along with current laws and authorisations. To ensure these standards were met the management principle which emerged was 'to minimise as best as practical the human influences that will disrupt the quality of life that society demands.'
In order to assess the effectiveness of environmental protection methods the performance of the various methods should be monitored. Particular laws, management practices and structures may be measured individually. Alternatively the range of methods may be assessed by monitoring on a regional basis. In the Alligator Rivers Region one approach in monitoring the regional efficiency of protection methods is to measure parameters of the soil environment over time. The objectives of a monitoring programme are not to pass judgement on the success or failure or environmental protection techniques but merely to provide factual data on the degree to which the techniques are minimising effects of mining on the environment.

A history of the soil monitoring programme now follows, finally focusing on the aims, principles and objectives of the current soil monitoring project. This discussion is then followed by principles used to interpret results and concludes with the future direction of the soil monitoring programme.

HISTORICAL DEVELOPMENT

In 1978 environmental monitoring on a scale envisaged for the Alligator Rivers Region had not been previously tried in Australia, so while there existed a body of expertise capable of carrying out a monitoring programme, there was a shortage of experience and knowledge of what was required from the monitoring programme. This was particularly true for heavy metal monitoring which was relatively new to Australian soil studies.

To overcome this deficiency in experience two workshops during 1978 and 1979 were held at which the Land Conservation Unit was deemed to be the government authority responsible for carrying out the soil monitoring programme. This was because the Land Conservation Unit was already responsible for soil studies in the Northern Territory and had relevant local expertise. The workshops developed the objectives, principles and procedures for the soil monitoring project that followed.

The primary aim was to "find out how much metal transports and where it resides" (Evans 1978). In doing so the programme would provide "a long-term monitor of more permanent effects". The workshops considered it "unlikely that significant increases in metal concentration would be expected at most sites for some years after mining." These principles are still applicable to the current monitoring programme.

The workshops identified that the programme would involve two phases. Phase one incorporated soil surveys and collection of at least two years of samples prior to mining to be held as a reference library. The second phase was sampling of selected sites periodically and checking analytical results with those prior to mining. Samples were to be taken from those areas where water and wind would transport heavy metals. These broad procedures were incorporated into the monitoring programme.

While the overall principles remained constant details of the methodology developed at the workshops were subsequently considered impractical and costly in relationship to the whole monitoring programme in the Alligator Rivers Region. For example, the initial phase of establishing a base-line set of data required 2-3,000 profiles to be sampled. On the other hand the soil monitoring phase involved collection of only 250 samples. Other concepts such as the sampling of 10 cm depth intervals, would appear in hindsight to have been more appropriate (White 1983, this Workshop).
Nevertheless, while details of techniques required to collect data were discussed and examined in detail at these early workshops, little consideration was given to the techniques required to interpret the information that would be generated. The programme that was initiated in 1979, although reduced in scale from that initially conceived, still followed those principles discussed above. The methods used are discussed in White and Day (1982) and are fundamentally the same as those used in the present programme (White 1983, this Workshop). During 1979 and 1980 the problem of data interpretation was recognised. As an aid to data interpretation the soil monitoring programme has sought to use computer based methods (Findlater 1983, this Workshop).

In 1981 the attention of the soil monitoring programme changed subtly from purely regional monitoring to include regional monitoring and local surveillance of mining operations. The mining companies were then required to carry out their own monitoring programmes on-site. These programmes are now carried out under the surveillance of the supervising authority namely the Land Conservation Unit. The change in emphasis of the monitoring programme arose as a result of concern over an alleged contamination of the Nabarlek mine site. This concern was coupled with a desire to reduce government involvement in monitoring within mining project areas.

These series of events have lead to the development of the principles and practices of the current soil monitoring programme discussed below.

THE SOIL MONITORING PROGRAMME

Basic Principles

The aims of the soil monitoring programme have been defined by the Land Conservation Unit as:

(i) to gain an understanding of the spatial distribution of landform and soils within the Alligator Rivers Region and more specifically the project areas;

(ii) to monitor for pollution and environmental effects arising from the mining and processing operations.

The second aim can be further defined as monitoring for changes in soil chemistry in respect to contaminants from spillage of water from ponds, seepage of contaminated water from ponds and deposition of contaminants aerially dispersed from the mining and processing operations. Soil monitoring, per se, must be considered as a secondary tool in monitoring the environmental impact of uranium mining on the Alligator Rivers Region, as comprehensive aquatic, biological and atmospheric monitoring is in progress.

As a means to achieve these central objectives the soil monitoring programme seeks to:

1. Review existing soil and landform data in the Alligator Rivers Region and to carry out where necessary further soil survey investigations.

2. Select and establish permanent soil monitoring sites about the operational and proposed mine project areas within the region.
3. Obtain base-line heavy metal levels for these sites and monitor the heavy metal content regularly.

4. Securely store soil samples from the region for future checking when required.

Compliance with the stated objectives should continue until they have been achieved. Objectives 2, 3 and 4 concerning location of monitoring sites, collection of base-line data and establishment of a reference library have been achieved for mining projects in operation. With the commencement of new mining projects these objectives will need to be re-examined.

Objectives 1 and 3 relate to extension of the Land Conservation Unit's knowledge of landform and soils in the region and periodic sampling of monitoring sites. These two objectives will not be attained until at least mining ceases or the overall aims of the environmental monitoring programme have been achieved.

Rationale of the present methods

 Broadly, after the initial base-line information has been collected, samples will be taken once during the dry season every two to five years, according to the procedure in White (1983, this Workshop). All sites are to be sampled at regular depth intervals to 150 cm where possible. The rationale for several aspects of this approach will now be examined.

Soils in the Alligator Rivers Region need only be sampled once during the dry season. The concept on which this is based is that the environment is a stop-go system. With water as the medium, heavy metals are moved during the wet season from their source to sinks, such as the soil. During the dry season it is thought the concentrations of heavy metals in the soil will remain reasonably static. Sampling soils during the wet season is of doubtful value and it would be more appropriate to monitor water quality during this period.

The soil monitoring programme has never aimed to measure short term changes in concentration of elements in the soil and therefore monitoring will take place at a 2-5 year turn around basis. With inherent environmental variability, and concentrations of elements, analytical methods are not expected to be sensitive to small annual changes. However, with cumulative effects over time, any changes that have occurred should be detected after a number of years.

Samples are taken to a depth of 150 cm because there is some evidence that not all heavy metals are fixed in surface horizons (Findlater and White, in press). Other concepts such as changing from sampling on an horizon basis to set depths are discussed in White (1983, this Workshop). Likewise the choice of analytical methods and selection of elements to be monitored have been discussed by other workers (White and Day 1982, White 1983, this Workshop). These topics will not be discussed in this paper.

PROBLEM IDENTIFICATION AND INTERPRETATION OF RESULTS

At the two workshops held in 1978 and 1979 the aim of the soil monitoring project was defined and the field procedures to collect data suggested.
However, little mention was made as to whether or not the data would provide the answer to the real question that now confronts the monitoring programme.

The question that needs to be answered, is: Has the concentration of heavy metals in the soils increased over a period of time from pre-mining concentrations? Specifically, the monitoring project needs to identify what constitutes an increase in heavy metal concentration.

At a particular monitoring site the recorded concentration of heavy metals may vary widely due to environmental variation and variability resulting from analytical techniques. In the field identical levels from five cores are bulked and only one analytical value is obtained for each level (White 1983, this Workshop). If just one value is compared with another recorded in the previous year, it is difficult to judge if the value is within the expected range in metal concentration. This is because there is little information on the expected variability in concentration. Because of this difficulty, several techniques are employed to obtain criteria by which to judge if the measured metal concentration has remained static from previous years.

A pure statistical approach to obtain estimates of sample variability involves collection of a large number of samples and corresponding chemical analyses. Such an approach is physically impractical and costly. More subjective methods will need to be employed to obtain estimates of the range in metal concentrations at soil monitoring sites. In particular, concentrations of elements in each profile can be graphed over time to highlight any unusual patterns. These patterns can then be investigated further. In addition, the statistical variation can be calculated for selected sites. The variability for these sites can then be extrapolated to estimate the variability at other sites. If a value lies within this variation then changes in concentration may be ignored. Unusual heavy metal concentrations will also be judged in relation to features of landform and soil morphology.

CONCLUSIONS AND FUTURE EMPHASIS

The nature of the soil monitoring programme has changed from when it was first conceived in 1978. Objectives are still similar while techniques have been modified as a result of some four years of experience.

The monitoring programme will continue with the principles and objectives discussed in this paper. Future emphasis will be placed on gaining estimates of variation in metal concentration. Techniques need to be developed to enable rapid judgements on whether particular analytical results constitute increases in metal concentrations.

Monitoring of emerging mining projects would follow a similar philosophy to that of the present programme. However, knowledge of heavy metal concentrations in soils within relevant project areas should be obtained prior to construction. This would give an estimate of the local variation in concentration in the event of any pollution. Additional monitoring sites should be placed near structures when the construction phase is complete. Sites near these additional structures need only to be sampled if evidence elsewhere suggests increases in metal concentrations.
Finally, it must be emphasised that the monitoring programme is a secondary tool. The programme expects only to detect changes after several years of mining. It is highly unlikely that a decision can be reached as to increases in heavy metal concentration following one particular year of operation of a mine.

REFERENCES


ENVIRONMENTAL MONITORING - METHODS
EMPLOYED IN THE SOIL MONITORING
PROGRAMME ALLIGATOR RIVERS REGION,
1979 - 1982

L.A. WHITE
Soil Conservation Authority
Gotham Road, Victoria

SUMMARY

For the past three years the Land Conservation Unit has been responsible for soil monitoring in the Uranium Province of the Northern Territory. This paper briefly discusses both the chemical and physical methods employed in the study. Some of the technical problems encountered are mentioned.

INTRODUCTION

The Alligator Rivers Region is host to substantial deposits of Uranium. However, unlike other forms of mining, uranium exploration invokes particular concern because of the potential long term pollution hazard.

Experiences at Rum Jungle, and the close proximity of the Alligator Rivers mining areas to a national park have led to strict requirements being set down for the mining and extraction of the ore bodies.

Proposed mining in the area gave rise to the Alligator Rivers Fact Finding Study (O'Brien 1973), a federal judicial enquiry (Fox et al. 1976, 1977) and finally a scientific workshop in August 1978 to establish guidelines for environmental monitoring. Recommendations from a soils and metals subgroup (Evans 1978) of this workshop led to the introduction of soil heavy metal monitoring in the region. The responsibility for this project was assigned to the Conservation Commission of the Northern Territory, in particular to the Land Conservation Unit. Further guidelines for the project were developed during a workshop held in Darwin in March 1979.

This paper shall detail briefly procedures used for soil monitoring by the Land Conservation Unit, highlighting some problems that have arisen. Results and fuller explanations of methods may be found in publications of the Land Conservation Unit, Darwin (White and Gigliotti 1982, in press; White and May 1982; White in press a, b; White and McLeod in press a, b).
METHOD

The Land Conservation Unit commenced its soil monitoring studies in August 1979. This project encompasses two separate aspects, soil surveying and long term chemical monitoring.

On a regional basis, soil inventory studies were principally carried out to identify land units at the scales of 1:50,000 and 1:25,000, delineating areas of relatively similar land form, soils and vegetation (Wells 1979; White et al. 1982; Day and Czachorowski 1982). More detailed local soil studies at 1:10,000 were undertaken about the mine areas (Wells 1979; Findlater in press; White and McLeod in press c, d).

Land unit and soil studies involved air-photo interpretation (black and white; 1:16,000 scale) and field investigations. Soil samples were obtained with a 10 cm diameter auger to a depth of 150 cm, wherever possible.

Soils sampled for chemical investigations were located at well defined areas. Sites believed appropriate for this aspect of the project were areas downstream of mine structures, on the broad drainage floors of the Magela and Cooper Creek flood plains, and on the predominately down wind situations where deposition from dust fallout was regarded as a possibility.

Sites were initially located on aerial photographs and permanently marked in the field with a labelled star picket. A monitoring site was considered to include the area of a 10 metre radius circle. Numbers of sites for each subregion over the 1979-1981 period are shown in Table 1 and the approximate location of sites sampled in 1980 are given in Figures 1-5.

Table 1. SOIL MONITORING SITES SAMPLED OVER THE THREE-YEAR PERIOD 1979-1981

<table>
<thead>
<tr>
<th>SUB-REGION</th>
<th>1979</th>
<th>1980</th>
<th>1981</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper Creek Flood Plain</td>
<td>18</td>
<td>18</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Koongarra</td>
<td>16</td>
<td>37</td>
<td>34</td>
<td>50</td>
</tr>
<tr>
<td>Magela Creek Flood Plain</td>
<td>29</td>
<td>32</td>
<td>19</td>
<td>100</td>
</tr>
<tr>
<td>Nabarlek</td>
<td>39</td>
<td>39</td>
<td>37</td>
<td>60</td>
</tr>
<tr>
<td>Ranger</td>
<td>50</td>
<td>67</td>
<td>61</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>152</td>
<td>248</td>
<td>167</td>
<td>308</td>
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</table>

Sampling operations were restricted to the dry season months of August to September with flood plain sampling being undertaken in October.

Except in the flood plain situations at least five cores were taken and bulked at each site; on the Magela and Cooper Creek flood plains only one core to a depth of 150 cm was taken per site, but five surface samples were bulked.
In the first two years of the project (1979 and 1980), cores were separated on an horizon basis, but in 1981 standard depth sampling procedures were adopted. These were 0-5, 5-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100, 100-110, 110-120, 120-130, 130-140, 140-150 cm.

Soils at all monitoring sites were morphologically described and 2-3 kilograms of each bulked "level" (horizon depth interval) was returned to the laboratory in a heavy duty paper satchel, air dried at 40°C, gravel sorted, crushed (<2 mm) and stored in airtight plastic boxes for future reference.

Chemical analyses were undertaken on a 200 to 300 g subsample (of each level), with some reduction in the extent of the analyses performed occurring over the years. The analyses performed were as follows:

(i) pH extraction 1:5 soil-deionised water mix read at 20°C (detection limit 0.05 unit).

(ii) Electrical Conductivity extraction 1:5 soil-deionised water mix potentiometrically at 25°C.


(iv) Exchangeable Cations, Sodium, Potassium, Calcium and Magnesium Cation Exchange Capacity via leaching with NH₄Cl, and NaNO₃ respectively; readings by Atomic Absorption Spectrophotometer. Reference Tucker (1960); Tucker (1974); Tucker and Beatty (1974).

(v) Total Cu, Pb, Mn, Zn via Perchloric/Nitric acid digest followed by AAS. (Readings as ppm, detection limits 1 ppm).

(vi) Total Uranium following Perchloric/Nitric acid digest determined by Fluorimetry. (Readings as ppm, detection limits 0.1 ppm). Reference Pakalns (1970).

(vii) Total Sulphate following Perchloric/Nitric acid digest via turbidimetric determination as Barium Sulphate. Reference Basson and van Staden (1978).

(viii) Total Molybdenum via Perchloric/Nitric acid digestion. Thiocyanate complex extracted into an organic solvent and read via Atomic Absorption Spectrophotometer. (Readings as ppm, detection limits 0.5 ppm).

(ix) Total Cadmium via Perchloric/Nitric acid digests followed by AAS. (Readings as ppm, detection limits 1.00 ppm).

(x) Total Arsenic and Mercury via Perchloric/Nitric acid digest with vapour hydride determination. (Readings as ppm, detection limits, arsenic 2.0 ppm, mercury 0.005 ppm).

(xi) Total Radium following a Perchloric/Nitric acid digest. Ra released is determined by isotope counting equipment. Reference ALPHA, AWWA, WPCF (1975).
(xii) Total P, K, S, Ba, Th via XRF analysis following the brique-ting of a soil sample. (Readings are by an X-ray fluorescence technique). Reference Norrish and Hutton (1964).


(xiv) EDTA Soluble Cu, Zn, Mn, Pb via EDTA Ammonium Carbonate soil mix. (Readings as ppm, detection limits Cu, Zn 0.2 ppm, Mn, Pb 0.4 ppm). Reference Trierweiler and Lindsay (1969).

(xv) Bicarbonate Phosphorus via extraction of 1:100 soil/0.5 M Sodium Bicarbonate solution as pH 8.5 and 20°C read colorimetrically. Reference Salt (1968).

(xvi) Bicarbonate Potassium via extraction of 1:100 soil/0.5 M Sodium Bicarbonate solution at pH 8.5 and 20°C read by AAS.


(xviii) Clay mineral analysis determined by comparison of diffraction patterns resulting from magnesium and glycerol treatment of a soil fraction.

DISCUSSION

Although soil monitoring sites are located throughout the Alligator Rivers Region, they are not intended to yield chemical data applicable to the whole area. Restricted selection of monitoring sites to the lower topographic positions (generally downslope of the mine site) would bias a complete regional appraisal.

The change in sample selection technique from the horizon approach to the depth method now allows for a speedier and more practical use of resources through computer sorting of results. However, depth sampling is felt to be less accurate in selecting the area in profile which is most likely to be affected by introduction of pollutants, since the depths selected cut across horizon boundaries.

The system of sampling to a depth of 150 cm allows for most contingencies already encountered by other soil monitoring studies. It may also enable early detection of soil/water movements not picked up by the general 0-5 or 0-10 cm approaches of other workers.

Estimation of total heavy metal levels has not been routinely carried out in previous soil studies by the Land Conservation Unit. As a consequence, the analytical method selected, that of a nitric-perchloric (HNO₃/HClO₄) digest, relied upon advice from outside the unit (Douglas pers. comm.; Hart pers. comm.; Sorentino pers. comm.).
A number of other total digest techniques were also reviewed; these included the processes of hydrogen fluoride ($\text{HF} \text{ @ } 105^\circ \text{C}$), sodium peroxide fusion ($\text{Na}_2\text{O}_2 \text{ @ } 900^\circ \text{C}$), and aqua regia (a 1:3 $\text{HNO}_3/\text{HCl}$ solution $\text{ @ } 180^\circ \text{C}$). Both the HF and $\text{Na}_2\text{O}_2$ techniques are considered more vigorous than $\text{HNO}_3/\text{HClO}_4$ and would be expected to yield almost all metals, including those bound in the clay silica matrix, into solution. However, both these procedures have safety difficulties and prove costly to perform. Other studies also concerned with heavy metal trace elements in the Alligator Rivers Region employed an aqua regia digest (Davey and Conway 1974; Morley 1981). In contrast, studies by workers outside the Uranium province (Tiller et al. 1975; Merry and Tiller 1978; Clayton and Tiller 1979) suggest that the ethylenediaminetetra-acetic acid (EDTA) procedure should be used for the determination of the more labile heavy metal contents of soils for environmental studies.

In an effort to clarify and accommodate this diversity of opinion, it was decided that for the baseline studies, both total and DTA extractable methods would be employed.

The question as to what extraction technique should be adopted in future soil monitoring programmes in each project area is, however, yet unresolved. The estimate of total element when used as the sole measure of "pollutant" level does not distinguish between more labile fractions of the element and hence will not enable a meaningful evaluation of possible environmental effects. Furthermore, analytical detection limits for more labile forms of each element are more sensitive (0.1 ppm) than those for the total element (1-2 ppm). For these reasons it is recommended the EDTA extraction technique be adopted in future soil monitoring programmes now that levels have been established.

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FIGURE 1

COOPER'S CREEK FLOOD PLAIN - 1980

HILLS
CREEKS
ROAD
MONITORING SITE
FLOOD PLAIN

ARUHEM LAND
ABORIGINAL RESERVE

72
70

Cooper Lagoon

Cooper Creek

Borradaile

CREEKS ROAD MONITORING SITE FLOOD PLAIN

1 0 1 2 3 4 Km.
FIGURE 3. MAGELA FLOOD PLAIN - 1980

HILLS
CREEKS
FLOOD PLAINS
ROADS
MONITORING SITE

km 1 0 1 2 3 4 km

Magela Point
Mayomarpleford
Waterhole

To Arnhem
Cannon Hill

18.
APPLICATION OF EXISTING DATA MANAGEMENT TECHNOLOGY TO ENVIRONMENTAL MONITORING OF SOILS IN THE ALLIGATOR RIVERS REGION N.T.

P.A. FINDLAIER
Land Conservation Unit
Conservation Commission of the N.T.
Darwin N.T.

SUMMARY
The application of information systems for soil and related data has been widely tested in the field of resource surveys both in Australia and overseas. However, its application for environmental monitoring purposes is as yet essentially untried. This study sought to use existing data collection, information storage and retrieval systems and apply them to soil monitoring in the Alligator Rivers Region. In doing so the paper demonstrates that the application of existing technology and the use of a conventional resource inventory approach is still applicable to the environmental monitoring of soils.

INTRODUCTION
Late in 1978 and throughout 1979 the soil monitoring programme for the Alligator Rivers Region was defined and initiated. In the first year, the project generated over 8,000 chemical values for soil samples collected from regional monitoring sites. Accompanying this data were detailed pedological descriptions of each sample. In successive years further soil samples have been taken resulting in over 30,000 chemical values for soils of the Alligator Rivers Region. It is expected that samples will continue to be taken and analysed periodically.

The question then arises, "How is such a large quantity of data interpreted?" Ultimately, the data has to be displayed and summarised in a convenient form. To achieve this the data needs to be efficiently stored, easily retrieved and manipulated. This is best achieved using a computer based information system.

A number of information systems for the natural sciences are in operation in Canada (Dumanski et al. 1975), New Zealand (Lee et al. 1976), Australia (Scott 1978) and elsewhere around the world. All these systems were designed for large quantities of land resource information. It was following the workshop, 'Information Systems for Soil and Related Data,
Canberra, 1980', that one system, the CSIRO computer network (CSIRONET) and the WARIS programs, (Anon. 1974), was chosen to store, retrieve and manipulate the Alligator Rivers soil monitoring data.

The discussion which follows focuses on the application of Computer based technology for environmental data interpretation. Aspects of data collection, CSIRONET and WARIS programs are examined. This is followed by an illustration of the uses of the information system.

NATURE OF THE DATA

There are three main sources of data for the soil monitoring studies in the Alligator Rivers Region of the N.T. Most important are the results from soil analyses, followed by field data then areal data from air photographs and maps. Information from these sources is collected, manipulated and interpreted with greater efficiency if recorded systematically.

Several methods exist for preparing or converting data from the various sources to a form 'readable' by a computer (Kloosterman 1975; McDonald 1981). The methods range from specially prepared forms to recording data directly from an electronic meter onto a computer. The fewer transcriptions required, the less chance there is of error. The Land Conservation Unit sought to use those methods which minimised the number of steps to the computer for the least cost.

Analytical Data

Analytical Data from 1979 was input to the computer via IBM 80 character punch cards with little regard to format. Late in 1980 the data had to be reformed into a more convenient form. To overcome the problems associated with unformatted data, results from 1980 monitoring programme were first transcribed onto specially designed recording sheets (figure 1). Transcription and correction of both 1979 and 1980 data was very tedious and time consuming.

Since 1981 the soil monitoring data has been entered in fixed format directly onto a 1600 bpi 9 track magnetic tape by the analytical laboratory. A small amount of additional information such as site number sampling depth and horizons which aid to identify the sample are easily added interactively. However, for smaller quantities of data say approximately 60 samples it is less costly and more convenient to transcribe analytical information from laboratory reports onto the formatted recording sheets.

Field data

The methodology used is similar to other land resource surveys and soil investigations conducted by the Land Conservation Unit (Aldrick and Robinson 1972; Fogarty et al. 1979). As part of the soil monitoring programme in the Alligator Rivers Region descriptive data is collected in the field for both a general land resource survey and more specifically to describe the morphological features of each soil monitoring site (White 1983, this Workshop). In order to establish consistency between various workers in the region, terms used by Soil Survey Staff (1951), Northcote (1979) and Stace et al. (1968) were all initially used to form a data dictionary.
However, since the soil monitoring programme was commenced in 1979, a national standard is being set through the production of the "Australian Soil and Land Survey Field Handbook" (McDonald et al. in press) and is now being used as the data dictionary. The definitions provided by the handbook adequately cover all contingencies expected in the soil monitoring programme.

While analytical data is recorded directly on a machine readable medium like magnetic tape, such technology for field descriptive data although available is far too costly and cumbersome to use (Kloosterman 1975). Other methods such as cards punched in the field and marked sense forms input by optical character readers, have been tried in the field but have met with a number of difficulties (Kloosterman 1975; Bie and Schelling 1975; Hazelden et al. 1976; Lynch 1977).

At present the most widely used method for recording field descriptive data for computer input is a coding form, either multiple choice or of the fill-in type, which are then transcribed at a later date by keyboard onto a computer readable medium such as punch cards.

The fill-in type sheet used by McDonald (1981) and Queensland Department of Primary Industries (Anon. 1974), if used in the soil monitoring programme would most likely lead to errors caused by legibility and remembering codes. A trial coding sheet (figure 2) combining both a tick-off system and fill-in approach similar to that of the Canada Soil Information System (Dumonski et al. 1975) and Craze (1981) was adopted by the Land Conservation Unit. The data sheet has been used for two years and most problems encountered will be removed in a second draft planned for 1983.

Survey data collected at the commencement of the soil monitoring programme has not been recorded in an easily transcribable form to be read by a computer. However, later soil surveys at Koongarra, Ranger and Jabiluka have all been recorded in computer compatible form. Overall, the field description sheet (figure 2) has proved easy to use in the field, suitable for manual sorting, comprehensive yet concise and relatively efficient in transcribing data through a keyboard.

Areal Data

While the first surveys in the Alligator Rivers Region did not use computer based techniques, the maps incorporated in the reports arising from these surveys can now be stored on computer. The map boundaries may be stored by using a digitiser which when traced over the map, records the co-ordinates of the line segments. The maps can then be retrieved using suitable software and a plotter. Interpretive data from current surveys although not in computer readable form can be input if required.

THE CSIRONET AND THE WARIS PROGRAMS

Hardware Alternatives

In 1980 several hardware alternatives were available to the Land Conservation Unit. Those alternatives which involved purchasing a computer relied on some knowledge of the extent to which the hardware and associated
software would meet the requirements of the soil monitoring programme. Purchasing a computer would also rely on having experienced staff to operate the system. Because there was a lack of knowledge of the full requirements of a computing system for soil monitoring and no ready access to staff with computing experience it was decided to purchase computing time. In doing so staff would gain the necessary experience and knowledge of the computing requirements for the soil monitoring programme.

Computing time was available through the N.T. Government at no or little charge. However, the N.T. Government within the time required could not offer support for a soils information system. In addition other hardware such as plotters and digitisers would eventually have to be purchased. Because the options discussed above were not entirely suitable the CSIRONET was examined.

CSIRONET is a computing service run by CSIRO. The service operates by users writing their own programs or making their own selections from packages available on the system. The CSIRONET is accessed through an Australian wide network of mini-computers or "nodes" which communicate with the host, a Cyber 76 computer.

People with little previous computing experience can quickly become familiar with its basic operation. Researches have access to numerous peripheral devices for example digitisers, plotters and micro-fiche cameras. In particular, the CSIRONET had three environmental information systems in operation (Mackenzie and Smith 1977). They were FORDATA, a data based management system and two data file management systems INFOL (Anon. 1977) and WARIS (Anon. 1974). These programmes could be easily tested for their suitability for the Alligator Rivers' soil monitoring programme. Because of its versatility, support services and overall cost effectiveness the CSIRONET was chosen to test an information system.

WARIS

Of the three data management systems available through CSIRONET the WARIS programs (Anon. 1974) were chosen to gain the required experience because the programs had been developed for Queensland land resource survey data and the Department of Primary Industries would give support in adapting the programs for use in the Northern Territory.

WARIS consist of a number of programs which enable the user to cover four basic operations:

1. Input and Storage.
2. Editing.
3. Retrieval and manipulation.
4. Publication.

Input and Storage. There are three programs used to input and store data. One program describes the way the data is stored (format) while the other two programs, one of which the land Conservation Unit has written, reformat the data so as the soil monitoring data can be read by the WARIS programs.

Editing. Checking the data involves two programs which list similar data for a visual scan for inconsistencies and to check for errors such as whether the parameter should be an alpha character instead of numeric. All the errors are corrected interactively.
Retrieval and Manipulation. Retrieval is the most important operation as it allows data to be manipulated. Retrieval of the data involves extracting selected parameters then either listing or sorting in the values. The output can be sent to a number of peripheral devices such as a Visual Display Unit (VDU) or manipulated by other programs and "packages". In particular the WARIS programs cater for, descriptive statistics, frequency distribution and a correlation matrix. If these operations do not provide the right analyses, retrieved data can be manipulated by "packages" and utilities available on the CSIRONET, such as GENSTAT, GLIM and TAXON.

Publication. While the manipulation programs provide output in a form suitable for research, publication programs are available to produce the same output in a form suitable for reports. The programs have not been tried on field data but have been successfully used for analytical data.

APPLICATION OF THE WARIS PROGRAMS

The major proportion of the data in the soil monitoring information system is analytical data from 1979 through to 1982, inclusive. This data can be easily retrieved and conveniently formatted to be read by other programs. Within the scope of this paper it is not practical to give comprehensive examples of all the applications of the soil monitoring information system. What follows is a simple illustration of the manipulation of the Land Conservation Unit's soil monitoring data for the Ranger Uranium Mines project area.

The data which has either been transcribed onto the coding sheets (figure 1) or magnetic tape has a VDU image similar to that of figure 3. The WARIS programs 'know' which columns refer to particular parameters. In figure 3 for example the concentrations of uranium at site 10 are highlighted. As can be readily seen the data in this form is very difficult to interpret.

By using the retrieval program to extract particular parameters and print the data as in figure 4 the information can now be comprehended. Again the concentrations of uranium for site 10 have been highlighted. The output from the computer will give a quick visual check for any unusual values or trends in concentrations of particular parameters.

Alternatively, data can be manipulated by other WARIS programs. For example, to produce a correlation matrix. The data can also be combined with data from other years and by inputing into a GENSTAT program and using the 'GRAPH' directive, concentrations at the same site over time can be presented graphically as in figure 5. In addition all original analytical results are now being circulated cheaply and efficiently by sending the data directly on magnetic tape or using a publication program and copying the output (figure 6) onto microfiche.

These facilities are just a few of those available that are now being used by the Land Conservation Unit on the soil monitoring data. Many other routines are available, like regression analysis, analysis of variance and descriptive statistics.
CONCLUSIONS

Conventional methods have been used to collect information for the Alligator Rivers soil monitoring programme. The data has then been processed by using computer based technology developed specifically for land resource survey data in Queensland, by the Department of Primary Industries. In particular, methods of recording analytical and field data followed those of research in Canada, New Zealand, N.S.W. and Queensland and are systematic, comprehensive and easy to use. Queensland's Department of Primary Industries WARIS programs, in combination with other program packages and facilities on the CSIRONET have catered for most contingencies that have been asked of it.

All the analytical data from the soil monitoring program collected over the past four years is now on the CSIRONET. All current soil survey field data is in a computer coded form and maps can be stored on the CSIRONET if required. It is now possible to circulate analytical information quickly in more convenient forms such as microfiche, magnetic tape and paper with a greatly reduced chance of error. When the techniques have been refined the information will be processed faster and with greater precision than has been possible.

These improvements have occurred despite the fact that the monitoring information system is still being developed and assessed. If more advanced information systems are developed for soil monitoring the task of changing over from the WARIS programs will be much simpler now that the data is on computer.

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Northcote, K.H. (1979). A Factual Key for the recognition of Australian soils. 4th (Ed) CSIRO Adelaide, S.A.


| Project | Site | Survey | Sample No. | Sample No. | Total Exctractable | Conductivity | pH | % Total | % Clay | % Particle Size | % C | % D | Soil Total | P | K | S | Zn | Ni | Cu | Mn | Pb | Bi | Cd | Hg | As | Se | Br | Cl |
|---------|-----|--------|------------|------------|-------------------|-------------|----|---------|--------|---------------|-----|-----|------------|---|---|---|----|---|----|----|----|----|----|----|----|----|----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |

**FIG. 1. CODING FORMS USED FOR ANALYTICAL RESULTS FROM THE SOIL MONITORING PROGRAMME ALLIGATOR RIVERS REGION, N.T.**
FIG. 2 CODING FORM USED FOR FIELD DATA FROM THE SOIL MONITORING PROGRAMME ALLIGATOR RIVERS REGION N.T. (SIDE ONE ONLY)
FIG. 3  CARD IMAGE OF DATA FOR SITE 10, 1980 IN SOIL MONITORING INFORMATION SYSTEM.
FIG. 4 OUTPUT FROM WARIS PROGRAMS FOR EASY INTERPRETATION OF CONCENTRATION OF HEAVY METALS.

FIG. 5 A THREE YEAR COMPARISON OF URANIUM CONCENTRATIONS FOR SITE 10 RANGER (1979 to 1981).
ENVIRONMENTAL SOIL MONITORING
FOR URANIUM AND COPPER
AT RANGER AND NABARLEK
ALLIGATOR RIVERS REGION N.T.

P.A. FINDLATER
Land Conservation Unit
Conservation Commission of the N.T.
Darwin N.T.

L.A. White
Soil Conservation Authority
Cotham Road  Victoria

SUMMARY
Since 1979 soil samples have been analysed annually by the Land Conservation Unit from permanent monitoring sites about the uranium mines. Within this paper a selection of results from Ranger and Nabarlek mine sites are examined. Included are the distribution in soil profiles of uranium following nitric/perchloric digest along with soil copper determinations following nitric/perchloric digest and extractable EDTA. The discussion demonstrates that the techniques employed in the soil monitoring programme can produce consistent results over time where pollution is not expected. In cases where differences between years are large, possible explanations are proposed.

INTRODUCTION
This investigation forms part of a soil monitoring programme which studies the distribution of heavy metals in soils of the Alligator Rivers Region of the N.T. The soil monitoring programme conducted by the Land Conservation Unit commenced in 1979 due to the interest in mining uranium in the region. The philosophy, methods and data management techniques have been presented in Findlater (1983a, b, this Workshop), White and Day (1982), White (1983, this Workshop). This paper seeks to demonstrate that these principles and practices can provide reproducible results which form a suitable basis for the soil monitoring programme, which is to continue over the period of uranium mining.

Studies of the concentration of heavy metals in soils of the Alligator Rivers Region outside the Land Conservation Unit's soil monitoring programme have been limited. However, Davy and Conway (1974) analysed one metre depth composites of soil from the Magela flood plain for U, 210 Pb,
Ca, Mg, Cu, Pb, and Zn, together with profile distributions for U, 226 Ra, 210 Pb, 137 Cs, Cu, Pb and Zn. Davy and Conway's results indicate that in general heavy metals were evenly distributed both down the plain and within the soil profile. Pancontinental Mining Limited have also examined the distribution of heavy metals in soils about the proposed Jabiluka mine (Anon. 1979, Morley 1981). The early work (Anon. 1974) generally agreed with that of Davy and Conway (1974). The later study (Morley 1981) indicated marked variation in concentration between various locations and concentrations of trace elements were low in comparison to world standards.

It should be noted that the methods discussed above have not involved sampling over a number of years. Also the methods used different sampling techniques and chemical digestions to those used in the Land Conservation Unit's soil monitoring programme. For these reasons it is difficult to relate past work with the Land Conservation Unit's soil monitoring results in terms of reliability for the region.

SOILS AND METHODS

Soils of the region have been mapped at various scales by different soil surveyors. (Hooper 1969, Aldrick 1976, Wells 1979, White et al. 1982, Day and Czachowski in press). These surveyors describe a diverse range of soils from lithosols on ridges and escarpments to soils with a Principle Profile Forms of Ug5.5 (grey cracking clays) and Dd 2.12; 2.51 (humic gleys) on the flood plains.

Two workshops held in August 1978 and March 1979 in conjunction with previous studies in the region were used as a basis for planning the soil monitoring programme conducted by the Land Conservation Unit. Monitoring sites throughout the Alligator Rivers Region were selected and analysed according to the methods described in White and Day (1982) and White (1983, this Workshop).

Briefly, soil monitoring sites were located in those areas where water is ponded for long periods because they may concentrate sediments and associated heavy metals. Sampling involved bulking of five 10 cm diameter hand augered cores from selected levels (White 1983 this Workshop). Samples were dried and crushed and a subsample was then taken for chemical analysis. The digestion technique selected for total analysis was that of a nitric/perchloric process where the nitric digest stage was taken to insipient dryness prior to subsequent HClO₄ digest being undertaken. The more labile heavy metal fractions were extracted using ethylenediaminetetra-acetic acid (EDTA).

RESULTS

It is not within the scope of this investigation to present all the results from 248 permanent monitoring sites. Therefore, to meet the objectives of the paper a limited number of results were selected to illustrate the important features of the monitoring programme.

Of the four areas being studied Ranger, Nabarlek (including the Cooper Creek flood plain) Magela Creek flood plain and Koongarra, monitoring sites from both Ranger and Nabarlek were selected for examination in this paper. This is because both mining projects are already operational and so are of immediate interest.
Four sites out of 67 were selected from Ranger while 6 sites out of 66 were selected from Nabarlek (figures 1 and 2). The sites were chosen on the basis that they represented the more important monitoring sites being studied in the vicinity of the mines. In particular, all sites are located relatively near the mining operation downstream on major drainage lines and therefore of primary importance in the soil monitoring programme in terms of being contaminated.

Detailed descriptions of the monitoring sites are given in White and Gigliotti (1982). For the sites at both Ranger and Nabarlek textures of the soil profiles are variable because the parent materials are layered alluvium or colluvium. Sites R1 and R10 are medium textured (earthy loam) over clay and coarse textured (earthy sand) over sandy clay respectively. On the other hand sites R4 and R28 are coarse textured (siliceous sand) over clay and medium to fine textured (yellow earth) respectively. At Nabarlek both sites N1 and N12 are uniform coarse textured sands (earthy sands). Sites N14, N16, N18 and N22 are all fine textured soils (grey brown clay).

Based on the chemistry of the ore body and the mining process (Davy 1979) a spectrum of elements were investigated (White 1983, this Workshop). Uranium and copper were among those chosen for investigation and the results for these elements from the selected monitoring sites are discussed in this paper because of their relative importance.

The distributions of Total U and Cu from 1979 to 1982 for each site are given in figures 3 to 6 while that of EDTA extractable Cu for only sites R1, R4, R10 and R28 are given in figure 7. Figures 8, 9 and 10 compare repeat determinations of U, Total Cu and EDTA extractable Cu on 1980 samples taken from the Ranger monitoring sites.

Results may be incomplete for a number of reasons. For sites R1 and R4 in 1980 and 1981 the occurrence of a high water table, rock or hardpan at depth may have made retrieval of the sample using a hand auger difficult. Alternatively, as for site R28 (figure 7) no determinations were made for EDTA extractable copper in 1979. Similarly, in 1982 sites N1, N12, N14 and N22 (figures 5 and 6) were not sampled.

DISCUSSION

Under ideal conditions for sampling and chemical analysis and when contamination of the monitoring site has not occurred either as a result of man's activities or by other means the concentrations of elements over three to four years should be coincidental. However, even under the most stringent experimental conditions such a level of precision is rarely achieved. In the natural environment where there are many more parameters to contend with, a high level of precision is even more difficult to attain. Therefore within the Alligator Rivers Region variation in results of base line studies is expected.

Sources of variation include field sampling procedures, analytical methods and temporal and spacial environmental variability. The results discussed below demonstrate that any observed variation in these results can largely be attributed to analytical methods. Indeed White (in press) sent splits of the same sample for chemical analyses to various organisations involved in environmental monitoring in the Alligator Rivers Region. White (in
press) found differences in concentrations between splits, irrespective of the detection limits stated by each laboratory. If the soil monitoring results are within the analytical precision achieved by such comparisons between laboratories then the results from the soil monitoring programme can provide a suitable basis for future comparisons. This is providing there has been no contamination following the initial year of sampling.

**Total Uranium and Total Copper**

Between 1979 and 1982 concentrations of total U and total Cu in each of the soil profiles discussed in this paper have varied by approximately 5ppm for U and approximately 10 ppm for Cu (figures 3 to 6). Concentrations of U are near the detection limits while concentrations for total Cu are considerably higher than the detection limit.

Replicate analysis on subsamples (Figures 8 and 9) illustrate more clearly the possible source for the variation. Theoretically, the results should all lie on the line y = x. For total U, most values are within 30 percent of the line. Nevertheless, occurrences of wild values suggest results for U may vary by up to 4 ppm. Likewise concentrations of total Cu may vary by up to 10 ppm for a particular sample. The observed variation in concentration of total U and total Cu over the four years is therefore within the observed precision of the analytical techniques used.

In particular, the source of the variation can then be largely attributed to the analytical methods rather than field techniques and environmental factors. For example, Site R28 in 1982, had high total U concentrations below 30 cm (figure 3). Repeat determinations on the 70 to 80 cm depth sample gave a total U concentration half that of the initial result which suggests analytical error rather than contamination.

However, not all the inconsistencies in the data are caused by the precision of analytical methods used. Both sites N14 and N18 also have observable discrepancies in total U concentrations. The variation of total U in successive years at both N14 and N18 is approximately 10 ppm and is more than can be expected from analytical precision observed in repeated determinations shown in figure 8. Similarly, site N14 also has anomalously high total Cu and it distribution mirrors, the distribution of total U at that site.

The anomalous values at sites N14 and N18 are most likely due to the natural differences in the spatial distribution of elements at the monitoring sites. Contamination of these sites by natural or anthropogenic processes is considered unlikely. At present, for site N14, there is little evidence to suggest that if contamination occurred recently total U and Cu would only accumulate in the mid profile and not at the surface or at depth. Likewise, the unusually low concentration of U at N18 in 1980 is inconsistent with the distributions observed in 1979 and 1981 and may be considered a result of difference in spatial distribution.

**EDTA Extractable Copper**

Over the four years 1979 to 1982 concentrations of EDTA Extractable Cu have generally varied by less than 1 ppm for sites R1, R4, R10 and R28.
(figure 7). EDTA extractable Cu concentrations are considerably less than Total Cu concentration. (Figures 5 and 6).

As was discussed with Total U and Cu concentrations, replicate analyses have been carried out for EDTA extractable Cu. The results (Figure 10) suggest that the observed variability in concentrations is within the variability arising from the analytical technique.

Site R28 is an exception with the surface concentration in 1980 varying by approximately 2.5 ppm. It is unlikely that the differences in concentrations have been caused by surface contamination. This is because the higher surface concentrations of subsequent years agree more closely with the expected profile trends and trends in other profiles in White and Gigliotti (1982).

CONCLUSIONS

The limited set of results presented demonstrate that the principles (Findlater 1983) and methods (White 1985) used in the soil monitoring program will produce consistent results within the limits of the analytical techniques. In particular the sequential monitoring of sites over a number of years to a maximum depth of 150 cm will establish a reliable history of heavy metal distribution.

Detailed investigations of the causes of anomalous values at the monitoring sites are outside the scope of the soil monitoring programme. Further studies examining the processes that influence heavy metal distribution in soils about the project areas would assist in explaining anomalies in the monitoring results.

Nevertheless, the soil monitoring program still needs to statistically determine an estimate of the variance of a particular sample. Once the degree of precision has been defined in this way and the degree of precision is acceptable, then the techniques used in the soil monitoring programme will be a suitable basis for future comparisons.

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FIG. 3 TOTAL URANIUM CONCENTRATION VS. SOIL DEPTH, RANGER SITES R1, R4, R10, R28 FROM 1979 TO 1982.
FIG. 4 TOTAL URANIUM CONCENTRATION VS. SOIL DEPTH, NABARLEK SITES N1, N12, N14, N16, N18, N22 FROM 1979 TO 1982.

FIG. 5  TOTAL COPPER CONCENTRATION VS. SOIL DEPTH, RANGER SITES R1, R4, R10, R28 FROM 1979 TO 1982

FIG. 6  TOTAL COPPER CONCENTRATION VS. SOIL DEPTH, NAARLEK SITES N1, N12, N14, N16, N22 FROM 1979 TO 1982

FIG. 7 EDTA EXTRACTABLE COPPER CONCENTRATION VS. SOIL DEPTH, RANGER SITES R1, R4, R10, R28 FROM 1979 TO 1982.

FIG. 8 TOTAL URANIUM CONCENTRATIONS ON SPLITS OF THE SAME SAMPLE FROM SELECTED SITES, RANGER 1980.
FIG. 9 TOTAL COPPER CONCENTRATIONS ON SPLITS OF THE SAME SAMPLE FROM SELECTED SITES, RANGER 1980.
FIG. 10 EDTA EXTRACTABLE COPPER CONCENTRATIONS ON SPLITS OF THE SAME SAMPLE FROM SELECTED SITES, RANGER 1980.
Technical Memorandum
85/5

REVISED CLASSIFICATION OF EARTH SOILS
OF THE DALY BASIN, N.T.

S.J. Lucas*, K.J. Day† and B. Wood*

*Soil and Land Resources Unit
Conservation Commission of the NT
DARWIN NT.

†Now with Department of
Primary Industries
AYR QLD

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Dalyi
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## CONTENTS

<table>
<thead>
<tr>
<th>ACKNOWLEDGEMENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ii)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SUMMARY</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

1. INTRODUCTION 6

2. A REVISED CLASSIFICATION SYSTEM
   2.1 Problems with the existing system 9
   2.2 Aim of the revision 10
   2.3 A classification base - Northcote or Stace? 11
   2.4 Criteria used to classify soils 12
   2.5 Methods used in revising the classification 13
   2.6 Soil classification 14

3. DESCRIPTION OF RED EARTH SOIL FAMILIES
   3.1 Review of previous classification 18
   3.2 Proposed classification 19

4. DESCRIPTION OF YELLOW EARTH SOIL FAMILIES
   4.1 Review of previous classification 38
   4.2 Proposed classification 40

5. DESCRIPTION OF GREY EARTH SOIL FAMILIES
   5.1 Review of previous classification 50

6. REFERENCES 54
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Location map of the Daly Basin.</td>
<td>2</td>
</tr>
<tr>
<td>2. Definition of earth profiles in the Daly Basin, N.T.</td>
<td>16</td>
</tr>
<tr>
<td>3. Main characteristics and criteria determining families of Daly Basin red, yellow and grey earth families.</td>
<td>17</td>
</tr>
<tr>
<td>4. Description of soils originally defined as alluvials (Aldrick 1972).</td>
<td>23</td>
</tr>
<tr>
<td>5. Representative profile classes of Blain sandy red earths.</td>
<td>28</td>
</tr>
<tr>
<td>6. Particle size information and appropriate boundaries of Blain sandy surfaced red earths (18 profiles).</td>
<td>29</td>
</tr>
<tr>
<td>7. Representative profile classes of Tippera loamy red earths.</td>
<td>31</td>
</tr>
<tr>
<td>8. Particle size information and approximate boundaries of Tippera loamy red earths (54 profiles).</td>
<td>33</td>
</tr>
<tr>
<td>9. Particle size information for the Tippera family.</td>
<td>35</td>
</tr>
<tr>
<td>10. Description of 'alluvial' soil family/profile class previously described as Edith 2 and Belbowie 2 (Aldrick 1972).</td>
<td>43</td>
</tr>
<tr>
<td>11. Representative profile classes of Elliott loamy yellow earths.</td>
<td>44</td>
</tr>
<tr>
<td>12. Particle size distribution boundaries of Elliott loamy yellow earths (5 profiles).</td>
<td>45</td>
</tr>
<tr>
<td>13. Representative profiles for the Jindare and Elizabeth profile classes of the Jindabeth family, and for the Claravale family.</td>
<td>49</td>
</tr>
<tr>
<td>14. Typical profiles for the grey earths (as per Aldrick 1972).</td>
<td>53</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Summary descriptions of the revised classification (May 1987).</td>
<td>4</td>
</tr>
<tr>
<td>2. Evolution of Daly Basin soil classification.</td>
<td>7</td>
</tr>
<tr>
<td>3. Historical and proposed classification of red earthy sands and red earths of the Daly Basin.</td>
<td>20</td>
</tr>
<tr>
<td>4. Summary of the main characteristics of the Blain and Tippera family soils (red earths).</td>
<td>26</td>
</tr>
<tr>
<td>5. Historical and proposed classification of yellow earthy sands and yellow earths of the Daly Basin.</td>
<td>41</td>
</tr>
<tr>
<td>6. Summary of the main characteristics of the Elliott and Jindabeth family soils (yellow earths).</td>
<td>47</td>
</tr>
<tr>
<td>7. Summary of the main characteristics of the Douglas and Narrakai family soils (grey earths).</td>
<td>52</td>
</tr>
</tbody>
</table>
SUMMARY

The Daly Basin is located in the Top End of the Northern Territory. In this report it refers to the extent of the Daly River Group of sediments and covers approximately 17 800 km² (Figure 1). It roughly coincides with the catchment of the Daly River and the area mapped as the Tipperary land system by Christian and Stewart (1953).

Classification of soils of the Daly Basin was first documented by Stewart (1956) and later by van de Graaff (1965). Aldrick (1972) provided the most detailed classification of soils of the Daly Basin and it is the system currently in use.

Each of these systems evolved as more detailed surveys were undertaken and more attention was applied to distinguishing between different soils at a finer level. In recent years, new areas have been mapped and previously mapped areas have been remapped in greater detail. Difficulties have been experienced with incorporating further data into the existing system. Furthermore, multidisciplinary work associated with agricultural projects has shown widespread misunderstanding of the present classification system and indicated the need for a review of the classification framework.

The soils of the Daly Basin with the greatest potential for agriculture are the earth soils. These are the soils on which research and development and hence, the soil classification revision, have been concentrated. The classification of other soils within the Basin will be subsequently investigated, in response to any increased demand for information regarding their use.

This report details a modified classification for the earth soils of the Daly Basin and also describes how it relates to past soil classification systems for this region. Chapter 2 discusses problems of the existing system, the aims of the revision, and the methodology and criteria used. Separate chapters have been designated for the red, yellow, and grey earths, respectively. Each chapter begins with a review of previous classification of the particular soils.
Figure 1. Location Map The Daly Basin
Revision has been most extensive in these areas:

(i) the concept of a family has been broadened, and series have been defined more accurately as profile classes;

(ii) consequently a number of red earth families have been combined;

(iii) a number of families of soils previously described as podzolic soils have been combined and reclassified as yellow and grey earths; and

(iv) definitions of families and profile classes have been presented in a more interpretive form.

A program of comprehensive field work over the whole Daly Basin will be undertaken to check the revised system. It is likely that the results of this work will require this report to be later amended.

Summary descriptions of profile classes currently recognised within the revised classification are presented in Table 1.
TABLE 1: Profile classes of the revised classification of earth soils of the Daly Basin (May 1987)

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<thead>
<tr>
<th>Great Soil Group</th>
<th>Family</th>
<th>Class</th>
<th>Description</th>
<th>Location of Reference Site</th>
<th>Grid Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daly fine sandy levee soils</td>
<td></td>
<td>'Daly'</td>
<td>Deep, gradational (Gn2.11-12), loamy sand surface to sandy clay loam after 1 m.</td>
<td>CSIRO Blain South</td>
<td>(5268 - 163627)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'Katherine'</td>
<td>Deep, gradational (Gn2.11-12), sand to sandy loam surface building to light clay or sandy clay after 1 m.</td>
<td>Scott Ck. Station Rd.</td>
<td>(5268 - 095526)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'Gypsy'</td>
<td>Moderately deep, uniform (Gn5.51), loam fine sandy surface to fine sandy clay loam or sandy clay (fine), few mottles.</td>
<td>Onloo Station Grid</td>
<td>(5170 - 442627)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'Edith'</td>
<td>Deep, gradational (Gn2.11-12), silty loam surface to silty clay (light) by 1.5m.</td>
<td>Tipperary Blain Block</td>
<td>(5170 - 317734)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'Belbowie'</td>
<td>Deep, gradational (Gn2.11-12), clay loam surface to light or medium clay with few mottles by 1.5m.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Earths</td>
<td>Blain sandy soils</td>
<td>Venn</td>
<td>Deep, gradational (Gn2.11-12), sand to sandy clay loam by 1.5m.</td>
<td>Airstrip Block Carabahiti</td>
<td>(5170 - 383563)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Willeroo</td>
<td>Deep, gradational (Gn2.11-12), sand surface, loamy sand A2/A3, to light clay (with sand) by 1.5m.</td>
<td>D.F.P. Exp. Site W.E.E.C.</td>
<td>(5369 - 914091)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ruby</td>
<td>Deep, gradational (Gn2.11-12), loamy sand surface, sandy loam A2/A3, to light clay (with sand) after 1 m.</td>
<td>Ceres Downs S1</td>
<td>(5170 - 591808)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tipperary</td>
<td>Deep, duplex (Gn4.51-52), sand surface to sandy clay loam by 0.6 m, sandy clay or medium clay by 1.5m.</td>
<td>Farm 2 Tipperary Stn.</td>
<td>(5170 - 306930)</td>
</tr>
<tr>
<td>Tipperary loamy soils</td>
<td></td>
<td>Oolloo</td>
<td>Deep, gradational to uniform (Gn2.11-12), sandy loam surface, sandy clay loam A2/A3, to clay loam or light clay by 1.5m.</td>
<td>Tipperary Block Carabahiti</td>
<td>(5170 - 383563)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kinswee</td>
<td>Deep, gradational (Gn2.11-12), sandy clay loam surface, clay loam A2/A3, light-medium clay by 1.5m.</td>
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<tr>
<td></td>
<td></td>
<td>Fenton</td>
<td>Deep, gradational (Gn2.11-12, Gn3.11-13), clay loam surface to medium or heavy clay by 1.5m, may have strongly structured B horizon.</td>
<td>Farm 2 Tipperary Stn.</td>
<td>(5170 - 306930)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kau</td>
<td>Deep, gradational (Gn2.11-14), loam fine sandy surface, fine sandy clay loam A2/A3, light-medium clay by 1.5m; 'fluffy' feel, textures may decrease with depth.</td>
<td>Kumbywamba D1</td>
<td>(5170 - 598789)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hayes</td>
<td>Deep, gradational (Gn2.11-12, 44.45), less red, sandy clay loam surface, clay loam A2/A3, light-medium clay by 1.5m with few to common gravels and mottles.</td>
<td>Jindare - Claravale Road</td>
<td>(5269 - 853477)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tindall</td>
<td>Deep, gradational (Gn2.11-12), generally clay loam surface and medium or heavy clay by 1.5m with banded structural layers.</td>
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</tr>
</tbody>
</table>
### TABLE 1: (Continued)

<table>
<thead>
<tr>
<th>Great Soil Group</th>
<th>Family</th>
<th>Class</th>
<th>Description</th>
<th>Location of Reference Site</th>
<th>Grid Reference*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthy Sands</td>
<td></td>
<td></td>
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<tr>
<td>Cockatoo coarse</td>
<td></td>
<td></td>
<td>Deep, red, uniform textured soils (Uc 5.22), sand surface to clayey sand or sandy loam after 1 m.</td>
<td></td>
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<tr>
<td>sandy soils</td>
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<tr>
<td>Manbulloo</td>
<td></td>
<td></td>
<td>Deep, red, uniform textured soils (Uc4.22), sand surface to sandy loam after 1 m.</td>
<td></td>
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<tr>
<td>Unbravarra</td>
<td></td>
<td></td>
<td>Deep, yellow, uniform textured (Uc4.21), sand surface to light sandy clay loam by 1.5 m mottled.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Fine loamy levee soils</td>
<td></td>
<td>Deep, gradational (Gn2.4,6), silty loam or clay loam surface to silty clay loam or medium clay by 1.5m; few to common mottles and concretions.</td>
<td></td>
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<tr>
<td>Yellow Earths</td>
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<tr>
<td>Elliot loamy</td>
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<tr>
<td>soils</td>
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<tr>
<td>King</td>
<td></td>
<td></td>
<td>Moderately deep, gradational (Gn0.76), light sandy clay loam surface to light clay by 1.5m; A horizon slightly gravelly (2-10%) B horizon moderately gravelly (20-50%)</td>
<td>Manbulloo CSIRO</td>
<td>5260 - 163627</td>
</tr>
<tr>
<td>Fienning</td>
<td></td>
<td></td>
<td>Deep, gradational (Gn2.62,65), sandy clay loam surface to light-medium clay by 1.5m; A horizon slightly gravelly (2-10%), gravel and mottles common (10-20%) in B horizon.</td>
<td>Kumbyechants - D1</td>
<td>5170 - 597799</td>
</tr>
<tr>
<td>Florina</td>
<td></td>
<td></td>
<td>Deep, gradational (Gn2.65), sandy loam or sandy clay loam surface to light-medium clay by 1.5m; gravel common (to many) throughout, illuvial clay and many red, yellow and grey mottles in B horizon.</td>
<td>Yellow-Grey Earth</td>
<td>5170 - 467669</td>
</tr>
<tr>
<td></td>
<td>Jindale sandy soils</td>
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<tr>
<td>Jindale</td>
<td></td>
<td></td>
<td>Moderately deep to deep, generally gradational (Gn2.64, Dy5.61), sand surface to light clay by 1.5m; gravel common in A horizon, B horizon has many gravelly and mottled, and obvious illuvial clay.</td>
<td>Douglas D.F.P. Florina Site</td>
<td>5170 - 468470</td>
</tr>
<tr>
<td>Elizabeth</td>
<td></td>
<td></td>
<td>Deep, gradational (Gn2.21,76), loamy sand surface to sandy clay loam or light clay by 1.5m; A horizon slightly gravelly, gravel and mottles common in B horizon.</td>
<td></td>
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<tr>
<td></td>
<td>Grey Earths</td>
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<td></td>
<td>Douglas</td>
<td></td>
<td>Deep, gradational to duplex (Gn2.86, Dy4.61), sand or loamy sand surface to sandy clay by 1.5m; B horizon has common to many mottles and illuvial clay.</td>
<td>Kumbyechants - Lake Block</td>
<td>5170 - 562772</td>
</tr>
<tr>
<td>sandy soils</td>
<td></td>
<td></td>
<td>Deep, gradational profiles (Gn 2.82,.84,.96), silty clay or silty clay loam surface to silty clay or medium clay by 1.5m; B horizon has common to many mottles and illuvial clay.</td>
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<tr>
<td></td>
<td>Harrahi</td>
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<td></td>
</tr>
<tr>
<td>loamy soils</td>
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</tr>
<tr>
<td></td>
<td>Earthy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sands</td>
<td>Clearvale nodular soils</td>
<td></td>
<td>Deep, uniform (Uc4.21,2.21), sand or loamy sand surface to sandy loam at depth; gravel varies from common to very abundant (greater than 50%).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. INTRODUCTION

Soils of the Daly Basin were first described and classified during the broad reconnaissance surveys completed by CSIRO in the mid-1950s. Stewart (1956) broadly described the properties of soils of the Top End and made the first attempt to classify them into families. After several years of research had been carried out at the Katherine CSIRO farms and with the completion of the land systems mapping of the Tipperary area, van de Graaff (1965) refined Stewart's classification. He provided more detailed descriptions of soil properties and narrowed the range of variation allowed within soil families. This latter survey over what was known as the 'Tipperary area' described most of the area now referred to as the Daly Basin.

In the early 1970's the Land Conservation Section, of the Department of the Northern Territory, undertook semi-detailed land resource mapping at a scale of 1:50 000 over much of the Daly Basin. Aldrick and Robinson (1972) documented the vegetation and soils by mapping and describing 'land units'. Although soil classification presented in this report was based on the previous framework of Stewart (1956) and van de Graaff (1965), it included some re-organisation and extension. This involved the addition of several new families, the subdivision of all soil families into series and in some cases, phases and types were noted. The evolution of the classification to this point is summarised in Table 2. Divisions across the table represent the changes in classification of particular soils under different systems. The bold horizontal lines represent major boundaries within classification systems. Aldrick (1973) took this a step further by producing an internal report entitled 'A Revised Classification of the Main Top End Soils - 1st Approximation'.

Aldrick's classifications were based on the Great Soil Group criteria developed by Stace et al. (1968). He defined a soil family as 'a distinct and easily recognisable group of soils with specific (not general) parent material and pedogenic relationships' (Aldrick 1973).

* now part of the Soil and Land Resources Unit of the Conservation Commission of the Northern Territory
TABLE 2: Evolution of Daly Basin soil classification and relationship with this review.

<table>
<thead>
<tr>
<th>Stewart (1956)</th>
<th>van de Graaff (1965)</th>
<th>Aldertek (1972)</th>
<th>Soil Generated in this review</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS.G. Family</td>
<td>GS.G. Family</td>
<td>Subgroup Family</td>
<td></td>
</tr>
<tr>
<td>Lattosite Red Earth</td>
<td>Cockatoo Red Earth</td>
<td>Cinema C.</td>
<td>Silica Sand Cypress Stall</td>
</tr>
<tr>
<td>Tippeta</td>
<td>Red Earth</td>
<td>C.S.C. Subgroup</td>
<td>Earthy Stall Cockatoo</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Sturt (1956)</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Yellow Podzolic</td>
<td>Elliott Creek Yellow Earth</td>
<td>Yellow Earth</td>
<td>Elliott Yellow Earth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latosite Podzolic</td>
<td>Flinton Sand Yellow Earth</td>
<td>Flinton Yellow Podzolic</td>
<td>Yellow Earth Yellow Earth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Meadow Podzolic</td>
<td>Narrakal Bottled Grey Brown Earth</td>
<td>Narrakal Eloyed Podzolic</td>
<td>Narrakal Eloyed Podzolic</td>
</tr>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prairie-Dominant</td>
<td>Witch Hal Phillips Ingrid</td>
<td>Hardin</td>
<td>Phillips Ingrid</td>
</tr>
</tbody>
</table>

* Great Soil Group (Steephen 1955) # Great Soil Group (Steen et al. 1968) C additional family described a gravelly equivalent not listed here.
These pedogenic relationships were inferred from geology, (augered) profile description and field observation.

This semi-detailed mapping by Aldrick and Robinson (1972) was of a scale such that workers spoke of the Great Soil Group or Subgroup (e.g. sandy or loamy red earth) more often than family or series names and this provided an adequate level of understanding and communication. Individual series were not mapped and mapping units commonly contained several soil families and often different Great Soil Groups.

However, with the increasing interest in cropping as a farming enterprise, more detailed mapping of areas containing arable soils was required. The Soil and Land Resources Unit extended the initial mapping of Aldrick and Robinson (1972) to cover almost the entire Daly Basin and carried out several more detailed surveys at 1:25 000 scale and larger. These surveys, while concentrated on the northern part of the Basin, have required the excavation and description of pits, the augering of soils to bedrock and the analysis of more than 150 profiles for particle size composition, moisture retention and nutrient status. This mapping allowed a more detailed definition of the soils and subsequently placed pressure on the application of the lower orders, (families, series and types), of Aldrick's soil classification. Aldrick (1973) foresaw the need for further revision of the soil classification when he stated: 'No doubt it ....(the classification).... will be revised as further facts are unearthed.'

This report represents the first part of this revision and details a revised classification system for the earth soils of the Daly Basin. The revision has involved a complete literature review and the perusal of the original raw data. However, the resulting framework is not as drastically different from that of Aldrick's (1972) as had been initially anticipated.

The soils considered in this report have previously been known in the Northern Territory as red earths, (alluvial, sandy and loamy), yellow earths, yellow podzolics and lateritic podzolics (Aldrick 1972).
2. A REVISED CLASSIFICATION SYSTEM

2.1 Problems with the existing system

The purpose of soil classification is to be able to group similar soils so that predictions can be made as to the behaviour of soils within each group. The U.S.D.A. stated that .... 'Classification should group soils into families of series about which we can make the largest number of important statements concerning the use of the soil for growing plants and for engineering purposes' (1975).

However, serious difficulties have been encountered when applying the existing system (Aldrick 1972) during detailed mapping. This stemmed from excessive overlap of family and series descriptions, particularly with respect to important morphological properties such as texture and trend. Probably the two groups of soils of greatest concern are the sandy surfaced red earth soils, and the yellow and grey surfaced earth soils presently classified as podzolics.

Many of the problems confronted arise from the taxonomic level ascribed to family and series and the criteria used for classification. More specifically:

(i) the hierarchy described by Aldrick (1972) is sometimes inconsistent with U.S.D.A. practice (1975). Because of the introduction of additional Great Soil Subgroups, viz the alluvial, sandy and loamy groups, the terms family and series as per U.S.D.A. (1975) are often used by Aldrick (1972) as equivalents to subgroups and families, respectively. Consequently, a large number of soil families were described, and of these, many should have been designated as series. In turn many of the series should have been designated as types.

(ii) Aldrick's classification is genetically based. Genetic processes are inferred from observations of the landscape and the soil profile, and hence the soil classification is subjective. Many of Aldrick's inferences may well be borne
out with subsequent analysis. However, those lacking a strong understanding of the local geomorphology and genetic processes find parts of the classification confusing; while pedologists invariably interpret processes and soil morphological features differently. This is a particular problem in the Northern Territory where staff turnover is relatively high and where new staff are often given responsibility for extending existing mapping as part of in service training.

The classification of yellow earths and podzolics are plagued with this latter problem. Earth soils in the Top End rarely show the development of clear textural contrast between the A and B horizon's, a distinct pale A2 or a strongly developed structure in the subsoil. However, Aldrick (1973) considered that podzolisation was occurring in some of these soils and consequently placed them in the podzolic Great Soil Groups, rather than the podzolic earth subgroup as suggested in Stace et al. (1968, P.276). Some aspects of the classification do not lend themselves to easy interpretation, particularly for those working outside the soil science discipline.

Ease of interpretation of Aldrick's work has been further restricted by the form in which it was presented. The classification was included as part of a comprehensive report detailing resource survey work over a large area. The format of publication at that time cramped the profile descriptions and made it very difficult for the reader to assimilate and compare profile information. After undertaking a comprehensive review of old and recent data, it was conceded that Aldrick's (1972) system stood up to the revision better than anticipated. It is considered that much of the confusion which currently exists today is a result of Aldrick's work not having been presented in an easily interpreted tabular form.

2.2 Aim of the revision

The aim of revising the existing classification is to allow a more objective description of the earth soils. This will enable pedologists, landholders and agronomists to more easily understand
the classification and therefore to also more adequately recognise and study the soils. The criteria used for the revised classification must be obvious in the field situation, but at the same time, it should also be consistent with those defined by other pedologists both in Australia and overseas.

The revised classification aims to present more easily interpreted definitions for the soil profile classes (series) recognised to date; while providing broad family descriptions to which new classes may be added as more information accumulates. However, sweeping changes would be unacceptable as the present nomenclature has been extensively used in published material and many workers are already familiar with its use. Consequently, soil classification nomenclature used in the past will be adhered to wherever practical, particularly in the higher orders.

Since the proposed system is to be field orientated, chemical data has not been considered as part of the classification and will be correlated later when the system has been proven to be practical, and applicable to the whole of the Daly Basin.

2.3 A classification base - Northcote or Stace?

The soil classification system used in the Daly Basin has been based on Stace et al. (1968) and Stephens (1953) and, now after having been in use for over two decades, is well established. In recent years however, increased emphasis on the morphological approach to soil classification has taken place, with greater use being made of the work of Northcote et al. (1975) and Northcote (1979).

The systems of Stace et al. (1968) and Northcote (1979) were studied and considered in the light of the aims of our classification revision. It was decided that a framework for family classification should be based on Stace et al. (1968), but that the principles of Northcote (1979) would still be used to assist in identifying classes within these families. The main restructuring requirement
was in the classification of the podzolic soils. Major changes to the classification framework included:

(i) utilising the definition of a yellow earth (Stace et al. 1968) more fully to encompass some of the soils previously described as yellow podzolics (Aldrick 1972); and

(ii) providing at the Great Soil Group level the 'grey earths', as per grey massive earths (Northcote et al. 1975) and similar soils (Coventry and Fett 1982), which had previously been classified as yellow and lateritic podzolics (Aldrick 1972).

2.4 Criteria used to classify soils

The criteria considered most appropriate to classify earth soils are as follows:

(1) colour of the B horizon (Northcote et al. 1979) and the presence of mottles (whole coloured or mottled);

(2) textural trends within the profile (U, G or D);

(3) relative trends in particle size distribution down the profile;

(4) texture of the immediate subsurface horizon*, (horizons determined on colour and texture changes from a 30 cm pit) and maximum clay content by a depth of 1.5 m;

(5) parent material; and

(6) gravel content, composition and distribution.

* Other features such as soil surface texture and consistence are only considered when classifying soils into phases or types, which are of more local agronomic importance.
2.5 Methods used in revising the classification

After reviewing earlier classifications (Stewart 1956, van de Graaff 1965, Aldrick 1972) it was decided to opt for the approach of re-examining and restructuring the classification system in an ascending hierarchical manner, starting with individual profile data.

Initially, soil cards and field notebook descriptions from the survey of Aldrick and Robinson (1972) were reviewed.

Very little analytical data was available for the large area in the central and eastern parts of the basin surveyed by Aldrick and Robinson (1972). The data collected were for profiles sampled on a horizon basis rather than including samples from set depths, and samples often spanned wide depth intervals, which limited their value for interpretation and comparison with other results.

In recent years, most work in the Daly Basin has been associated either with extending 1:50 000 scale mapping on Tipperary, Fish River and Douglas Stations, or with the more detailed mapping of areas being considered for cropping on the Agricultural Development and Marketing Authority (A.D.M.A.) Douglas and Ooloo Acquisition areas. Since 1981 and during these latter surveys, profiles have been sampled extensively on a set depth basis. Hence, most available data has been collected recently and the majority of this comes from areas outside that covered by the mapping and soil classification of Aldrick and Robinson (1972). However, a limited number of soils from the Jindare and Katherine District (including Manbulloo, Willeroo and Mataranka) have also been re-examined by digging pits and carrying out comprehensive analysis on the samples taken.

Particle size results have been determined from over 150 profiles and detailed comparisons have been made of the results. Part of this work involved the graphing of clay, fine and coarse sand components against depth, for each of the profiles.

These graphs substantiated the distinctions made in the field.
between Blain (sandy red earths) and Tippera (loamy red earths). Furthermore, regional differences could be distinguished for soils previously grouped as various soil families (Aldrick 1972).

In general, there is little variation between the chemical properties of Daly Basin earth soils, with the exception of the very sandy soils (e.g. Blain soils, particularly the Venn series). All soils of this region are infertile but some more so than others. This variation can be inferred from differences in parent material and texture, as well as from inferred processes such as leaching.

Data for yellow earths is mainly restricted to the loamy soils of the Douglas/Daly area and the CSIRO Manbulloo grazing trial site. These results showed such soils to have similar particle size trends as the red earths of the area. Virtually no analytical data was available for the soils previously described as podzolics, however some data for five profiles is now at hand.

2.5 Soil classification

This report only concerns classification of earth soils of the Daly Basin. van de Graaff (1965, P.69) considered over 90% of soils to have 'earth-type' profiles. He described their general characteristics as follows:

1. there are no sharply defined colour, textural, or structural horizons, but they merge gradually one with the next;

2. generally clay content increases gradually with depth but some soils have little change in clay content through the profile;

3. the soils lack pedality. Very sandy horizons may have single-grain structure but otherwise the soils are massive with varying amounts of visible pores which, in lower horizons, characteristically have thin clay-skin linings;
4. subsoil colours range from dark red through yellow-red, yellow-brown, brown, and greyish brown, and rusty mottling is general in the last three colours; and

5. the soils are medium acid to neutral in reaction and normally there is little change throughout the profile.

Within the Soil and Land Resources Unit, earths and earthy sands are separated according to subsoil textures (Figure 2.). Further subdivisions of earth soils are dealt with separately in the following sections and the families and classes within each are defined. A summary of this is provided in Figure 3.
Figure 2: Definition of earth profiles in the Daly Basin, N.T.

Soils

Siliceous Sands  Earth Soils*  Structured Clays*

Earthy Sands (Uc)  Earths** (U, G or D)

Subsoil texture  Subsoil texture
S - SL (LSCL rarely)  heavier than LSCL

These are the soils the revision addresses.

* as defined by Northcote (1979) and evident from a hand augered profile.
** detailed in Figure 3.
Figure 3: Main characteristics and criteria determining families of Daly Basin red, yellow and grey earth families.

Earth Soils of the Daly Basin
Massive with an earthy fabric; weakly differentiated horizons; predominantly gradational texture profiles; non-calcareous; neutral to slightly acid pH trends; clay mineralogy dominated by kaolinite.

Super Groups
- Subsoil texture < LSCL
- Subsoil texture > LSCL

Great Soil Groups
- Earthy Sands
  - Variable coloured subsoils; shallow to very deep profiles; red soils gravel and mottle free; others may have common gravel and mottle.
- Red Earths
  - Red coloured subsoils; deep profiles; thick B horizon with clay nodules or some structure in heavier soils, mottled subsoils rare.
- Yellow Earths
  - Yellow coloured subsoils; moderately deep to deep profiles; gravel and mottles common in subsoils.
- Grey Earths
  - Grey coloured subsoils; shallow to moderately deep profiles; many mottles in subsoils.

Families
- Clarksdale
  - Modular Sandy
  - Coonanba Course Sandy
- Gorge
  - Course Levee
- Daly
  - Fine Sandy Levee
- Edith
  - Fine Loamy Levee
- Blain
  - Sandy
- Tippens
  - Loamy
- Jindabu
  - Sandy
- Elliott
  - Loamy
- Douglas
  - Sandy
- Warrall
  - Loamy

Classes
- Un2.1 Un5.1
- Uc1.1 Un3.5
- Gm1.4
- Gn2.1
- Gn2.1 Un4.5
- Gn2.1 Un3.1
- Gn2.1
- Gm2.1
- Gm2.2 Un4.1
- Gm2.2 Un4.1
- Gm2.8 Un4.1
3. DESCRIPTION OF RED EARTH SOIL FAMILIES

Red earths are predominantly Gn soils, with Um and Dr profiles being less common. These soils must have a red subsoil (generally with a value/chroma of 5; Northcote et al. 1975*), although surface colours may be lighter. Profiles are generally massive and earthy throughout but some profiles may show varying degrees of structural development, particularly in subsoils with high clay contents (greater than 45%). They generally have slightly acid to neutral reaction trends. The maximum texture of the subsoil by 1.5 m must be heavier than light sandy clay loam.

3.1 Review of previous classifications

Within the Daly Basin, Stewart (1956) described four families of (lateritic) red earths as previously defined by Stephens (1953). These were the Cockatoo, Tippera, Manbulloo and Katherine families, the latter two being levee soils.

van de Graaff (1965) described a further eight red earth soil families, making a total of 12. Four of these 12 were sedentary and gravel free (Cockatoo, Venn, Blain and Tippera), with another four being gravelly equivalents of these (Coralie, Vivienne, Elaine and Xanthippe). The remaining four were again similar to Cockatoo, Venn, Blain and Tippera except that they were formed on alluvium (Manbulloo, Daly, Katherine and Edith). In drawing these analogies with the latter soils, van de Graaff's descriptions deviated significantly from that of Stewart's (1956) (Table 3).

van de Graaff (1965) was the first to distinguish between earths formed from alluvium and those formed from material in-situ. When compared with soils formed on in-situ material he reasoned that the lighter less red colours (5YR) of the alluvial soils indicated a less advanced state of maturity, and that the higher cation exchange

* Coventry (1982) states that value/chromas of 4 should be acceptable, e.g. 2.5YR 5/8.
capacities in the alluvium provided evidence of a greater agricultural potential.

Aldrick (1972) combined van de Graaff's families of gravelly and non-gravelly equivalents and retained the family descriptions and names for the non-gravelly and 'alluvial' soils already mentioned. However, he subdivided the red earths into sandy, loamy and alluvial Great Soil Subgroups and added several new families (Table 3). In the red earths, these included the Gypsy, Belbowie and Umbrawarra 'alluvials' located on levees and the Ooloo, Emu and Tindall soils thought to be of sedentary origin. The Ooloo, Emu and Tindall soil families described by Aldrick (1972) were a subdivision of van de Graaff's Tippera family, divided primarily on the basis of differences in lithology, soil texture and soil structure.

The new Ooloo family encompassed sandy surfaced soils which set hard, and appeared to have properties of both the Blain and Tippera soils. Aldrick (1972) also re-defined the Venn soil to be heavier textured than the Blain rather than lighter as described by van de Graaf (1965).

The authors of this report consider that in proposing his classification, Aldrick (1972) was describing series (soil profile classes) within van de Graaff's (1965) families when producing new families. He used the Great Soil Subgroups to replace the previously broadly described families (Table 3). Furthermore, the alluvial soils seem to have been over-subdivided and diverged from their original definitions. For example, van de Graaf's (1965) 'Edith' became Aldrick's (1972) 'Katherine', 'Edith', 'Belbowie' and 'Gypsy'.

3.2 Proposed classification

The classification proposed in this report has attempted to broaden the concept of a soil family and to make the soil classification more workable under field conditions. In so doing:
TABLE 3: Historical and proposed classification of red earthy sands and red earths of the Daly Basin.

<table>
<thead>
<tr>
<th>Stewart (1956)</th>
<th>w.m de Gama (1965)</th>
<th>Aldrick (1972)</th>
<th>Lucas et al. (1985)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>G.S.G.</strong></td>
<td><strong>Family</strong></td>
<td><strong>Sub-Group</strong></td>
<td><strong>G.S.G.</strong></td>
</tr>
<tr>
<td></td>
<td>Cockatoo</td>
<td>Meballooo</td>
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<td></td>
<td></td>
<td>Red Earths</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Alluvium</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Katherine</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Edith</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Venn (Vivienne)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blain (Elaine)</td>
<td></td>
</tr>
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</tbody>
</table>
(i) parent material as a criterion of classification has been emphasised more at the soil profile class rather than the family level;

(ii) the texture of the immediate subsurface 'diagnostic horizon (4 - 14 inches)' of Aldrick (1972) has been retained as an important soil profile class criteria (particularly in red earths); and

(iii) previously described soil families which have been difficult to distinguish or with overlapping properties have been combined.

Earth Soils of Alluvial Origin

Aldrick (1972) described an 'alluvial' subgroup of red earth soils. These soils are recognizable either by:

1. their obvious alluvial origins (i.e. their position in the landscape; or

2. evidence of layering.

Aldrick (1972) distinguished families in this group on the basis of their age and texture, which he found to be consistent with levee size and geomorphogeny. He also included siliceous sands, earthy sands and alluvial yellow earths soils in this subgroup because of their similar parent material and mode of origin. Seven families were described.

One of the aims of review is to have a classification based on observed soil characteristics wherever possible, rather than inferred genesis. As such, it is thought that the 'alluvial' subgroup should be incorporated within other families with which they have similar characteristics. However, Aldrick's descriptions (1972) will be maintained until detailed survey work presently being undertaken on the Katherine River 'levees' by the Soil and Land
Resources Unit provides further information to allow a more adequate classification of these soils. Until this information becomes available, suggested groupings to incorporate current thought are presented in Figure 4.

The Manbulloo and Umbrarwarra families (Aldrick 1972) are earthy sands rather than earths and the authors have described them as soil profile classes of the Gorge coarse levee family. Furthermore, it is proposed that the Daly, Gypsy and Katherine families (Aldrick 1972) should be classified as soil profile classes of the Daly fine sandy levee red earths (van de Graaff 1965). Aldrick's Edith and Belbowie series 1 soils would be more aptly re-defined as soil profile classes of the Edith fine loamy levee red earths (van de Graaff 1965) and the more yellow series of the Edith and Belbowie families (Aldrick 1972) should be grouped as fine loamy levee yellow earths; which are yet to be named.

**Earth soils developed in situ.**

Aldrick (1972) described a further six families of red earths within his sandy and loamy subgroups. Under the revised classification these subgroups have been disbanded and the number of families has been reduced to two. The Blain and Venn* families as described by van de Graaff (1965) and Aldrick (1972) have been combined within the Blain sandy red earth family. These soils have often been difficult to distinguish and agronomically have similar properties and potential problems. The revised classification has grouped the Ooloo, Tippera, Emu and Tindall families (Aldrick 1972) into the Tippera loamy surfaced family (as per van de Graaff 1965) (Table 3). Soils grouped under the old families are now considered soil profile classes of the Tippera family. General descriptions of each of the families are set out in Table 4.

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* The 'firm surfaced' heavier textured Venns described by Aldrick (1972) do not fit those first described by van de Graaff (1965). In the revised system these are accommodated in the Ruby soil profile class of the Blain family. The Venn name applies to a lighter soil profile class of Blain soils as described by van de Graaff (1965).
Figure 4: Descriptions of soils originally defined as alluvials (Aldrick 1972).

Earthy sands - Gorge levee soils (No sites).

SOIL SERIES: Manbuijou
NORTHEAST KEY: C8d 22 (G2) 14
DRAINAGE: Well or excessively well drained
PARENT MATERIAL: Course river alluvia, deposited from infrequent very high floods.

- Dark brown (5YR 3/2, 4/2), dark yellowish brown (7.5YR 4/2, 3/2) or dark reddish brown (5YR 3/2, 3/2) sand or loamy sand, loose; sandy fabric; pH 6.0-4.0.
- Yellowish red (5YR 4/2, 3/2) or dark reddish brown (7.5YR 3/2, 3/2) sand or loamy sand, loose to slightly hard; sandy or sandy-earthly fabric; pH 6.0-7.0. This horizon is sometimes an unbleached A2.
- Red (2.5YR 6/2, 8/2), yellowish red (7.5YR 4/2, 5/2) or earthy dark red (2.5YR 3/2) sandy or loamy sand or clayey sand, moist very friable; earthy or sandy-earthly fabric; pH 6.0-7.0.

SOIL SERIES: Umbrirogen
NORTHEAST KEY: C8d 64 (C4, 2/4)
DRAINAGE: Imperfect
PARENT MATERIAL: Course alluvial; found typically along Stoney Creek and the upper parts of the major rivers; derived originally from granite or Keweenaw sandstone.

- Very dark greyish brown (2.5YR 3/1) or dark brown (5YR 2/1) coarse sand or loamy sand, very friable; sandy or sandy-earthly fabric; pH 6.0-4.5.
- Yellowish brown (7.5YR 4/2, 5/2, 6/2) coarse sand or loamy sand, very friable; sandy or sandy-earthly fabric; pH 6.0-7.0. This horizon is usually an unbleached A2.
- Strong brown (7.5YR 4/2) sandy loam or sandy clay loam, hard or very hard; earthy fabric; pH 6.0-7.0. This horizon increases in texture and decreases in permeability with depth. Many red, yellow and grey, mottles are present and some clay skins.
Figure 4: (Continued)

Red Earths - Daly fine sandy levee soils (No sites).

SAND SERIES: Daly
NORTHCOKE KEY: Gr2.11, .12
DRAINAGE: Well or moderately well drained
PARENT MATERIAL: River alluvium. These are not common soils.

Reddish brown (SYR 3/2) or dark reddish brown (SYR 3/2, 3/4) or dark yellowish brown (SYR 3/4) sandy clay loam, slightly hard; sandy clay earthy fabric; pH 6.0-6.5.

SAND SERIES: Gypa
NORTHCOKE KEY: Gr3.51
DRAINAGE: Well or moderately well drained
PARENT MATERIAL: Creek alluvium; often distinctly layered. These are not common soils.

Reddish brown (SYR 3/2) or dark yellowish brown (SYR 3/4) fine sandy clay loam; hard; earthy fabric; pH 6.0-7.0.

SOIL SERIES: Katherine
NORTHCOKE KEY: Gr3.11, .12
DRAINAGE: Well or moderately well drained
PARENT MATERIAL: River alluvium; often distinctly layered. These are not common soils.

Red (2 SYR 4/6) or dark red (2 SYR 3/4) or yellowish (2 SYR 4/6) fine sandy clay loam, dark earthy or sandy earthy fabric; pH 6.0-7.0. A few yellow mottles may occur.

Dark reddish brown (SYR 3/2) or dark yellowish brown (SYR 3/4) dense sandy clay loam or fine sandy clay loam; dry hard or very hard, or moist friable; earthy fabric; pH 6.0-7.0. This horizon may be an incipient unbleached A2.

Dark reddish brown (SYR 3/4) or dark yellowish brown (SYR 3/4) fine sandy clay loam, dry hard or very hard, or moist friable; earthy fabric; pH 6.0-7.0.

Reddish brown (SYR 4/4) or yellowish red (SYR 4/4) fine sandy clay loam or fine sandy clay; dry extremely hard or moist firm; earthy fabric; pH 6.0-7.0. A few mottles may occur.

Red (2 SYR 4/6) or dark red (2 SYR 4/6) or dark yellowish red (SYR 4/6) sandy clay loam, grading to sandy clay or light clay, dry hard or moist firm; earthy fabric; pH 6.0-7.0. A few yellow mottles may occur. This horizon is transitional to a buried soil, formed in an older layer.

Dark brown (SYR 3/2) brown (SYR 3/3) or dark yellowish brown (SYR 4/4) sandy to light sandy loam, soil or slightly hard; earthy or sandy earthy fabric; pH 6.0-7.0.

Red (2 SYR 4/6) or dark red (2 SYR 4/6) or dark yellowish red (SYR 4/6) light to medium clay or sandy clay; dry very hard or moist firm; earthy fabric; pH 6.0-7.0. Yellow or whitish mottles are common.
Red Earths - Edith fine loamy levee soils (No sites).

**Red Earths - Edith fine loamy levee soils (No sites).**

**NAMES**

- Edith

**NORTHWEST KEY**

- G2

**DRAINAGE**

- Well or moderately well drained

**PARENT MATERIAL**

- River alluvium: deposition from annual floods.

**SORT SERIES**

- Edith

**NORTHWEST KEY**

- G2

**DRAINAGE**

- Moderately well drained

**PARENT MATERIAL**

- River alluvium: older levees.

**Figure 4:** (Continued)

Red Earths - Edith fine loamy levee soils (No sites).

**NORTHWEST KEY**

- G2

**DRAINAGE**

- Well or moderately well drained

**PARENT MATERIAL**

- River alluvium: deposition from annual floods.

**SORT SERIES**

- Edith

**NORTHWEST KEY**

- G2

**DRAINAGE**

- Moderately well drained

**PARENT MATERIAL**

- River alluvium: older levees.

**Figure 4:** (Continued)

Red Earths - Edith fine loamy levee soils (No sites).

**NORTHWEST KEY**

- G2

**DRAINAGE**

- Well or moderately well drained

**PARENT MATERIAL**

- River alluvium: deposition from annual floods.

**SORT SERIES**

- Edith

**NORTHWEST KEY**

- G2

**DRAINAGE**

- Moderately well drained

**PARENT MATERIAL**

- River alluvium: older levees.

**Figure 4:** (Continued)

Red Earths - Edith fine loamy levee soils (No sites).

**NORTHWEST KEY**

- G2

**DRAINAGE**

- Well or moderately well drained

**PARENT MATERIAL**

- River alluvium: deposition from annual floods.

**SORT SERIES**

- Edith

**NORTHWEST KEY**

- G2

**DRAINAGE**

- Moderately well drained

**PARENT MATERIAL**

- River alluvium: older levees.
Table 4: Summary of the main characteristics of the Blain and Tippera family soils (red earths).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Blain Family</th>
<th>Tippera Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>Very deep (7-12 m)</td>
<td>Variable (1-6 m)</td>
</tr>
<tr>
<td>Structure</td>
<td>Massive and earthy throughout.</td>
<td>Predominantly massive and earthy through out, abundant clay skins, varying degrees of development of clay nodules; banded structure in high clay content subsoils.</td>
</tr>
<tr>
<td>Colour</td>
<td>A horizon - dark reddish brown; B horizon - dark red, red or dusky red.</td>
<td>A horizon - dark reddish brown (less commonly dark brown); B horizon - dark red.</td>
</tr>
<tr>
<td>Profile Development</td>
<td>Usually weak</td>
<td>Weak</td>
</tr>
<tr>
<td>Horizon Boundaries</td>
<td>Generally gradual or diffuse boundaries except for a darker surface horizon.</td>
<td>Gradual or diffuse boundaries except for a darker surface horizon.</td>
</tr>
<tr>
<td>Reaction Trend</td>
<td>Neutral or slightly acid throughout.</td>
<td>Neutral to slightly acid throughout.</td>
</tr>
<tr>
<td>Gravel Content</td>
<td>None or very few.</td>
<td>Usually few, although Fe and Fe/Mn gravelly phases occur.</td>
</tr>
<tr>
<td>Drainage</td>
<td>Well-drained (free of mottles).</td>
<td>Usually well-drained.</td>
</tr>
<tr>
<td>Texture</td>
<td>Gradational or duplex profiles - conspicuous medium sized sand throughout.</td>
<td>Gradational profiles.</td>
</tr>
<tr>
<td>Surface</td>
<td>Sand, clayey sand, or loamy sand.</td>
<td>Up to clay loam (often lighter).</td>
</tr>
<tr>
<td>Immediate Sub-Surface</td>
<td>Sand, clayey sand, loamy sand or sandy loam.</td>
<td>Sandy clay loam, clay loam or light clay.</td>
</tr>
<tr>
<td>(10-30 cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsoil (1.5 m)</td>
<td>Clay loam or as heavy as medium clay with sand.</td>
<td>Light clay often heavier.</td>
</tr>
<tr>
<td>Surface Consistence</td>
<td>Loose or moderately weak, (weakly hard-setting).</td>
<td>At least very firm, (strongly hardsetting).</td>
</tr>
</tbody>
</table>
Aldrick (1972) described a total of seven series within the Blain and Venn families. The revised classification combines several of these and on present data recognises four soil profile classes of the Blain family. These have been named Venn, Willeroo, Ruby and Tipperary and are described diagramatically in Figure 5. Their previous designations and reference site locations are also included.

Particle size determinations have produced a wide range of values for Blain soils, as shown in Figure 6. Variation particularly in subsoil textures has been observed within small areas (Arndt et al. 1963, McLeod 1980). This may be due to the nature of the parent material (Aldrick 1972).

The Venn profile class is the lightest member with textures of sand at the surface gradually increasing to sandy clay loam at depth (1 m) (e.g. at the CSIRO Blain South site). A duplex profile characterises the Tipperary profile class which has a sand surface rapidly changing to a sandy clay B horizon (e.g. CSIRO Blain North site on Tipperary Station). The Willeroo profile class has gradational profiles and is heavier than the Venn soils throughout. Similarly, soils of the Ruby profile class also have gradational profiles but are heavier than the Willeroo soils throughout (e.g. Ruby Block on Ooloo Station). Particle size data reveals the sand component to be predominantly coarse in the south of the Basin (Venn and Willeroo profile classes), and to be fine in the north (Ruby and Tipperary profile classes) (see Figure 6). However, common to the family are very low silt contents throughout (under 5%) and 85-90% total sand in the top 20-30cm.

**Tippera family**

Characteristics of the Tippera family soils are summarised in Table 4.

Particle size results indicate that the Tippera family covers a wide range of clay contents. However, properties and trends within the family are consistent. Tippera soils have the highest surface clay...
Figure 5: Representative profile classes of Blain sandy surfaced red earths.

BLAIN - SANDY RED EARTH

VENN
On 2.11.12 (14,.15)
loose

- Sand-Loamy Sand: 5YR 3/3;
- Sandy-Loamy Sand: 2.5YR 3/4;
- Loamy Sand: 2.5YR 3/4;
- Sandy Loam: 2.5YR 3/4;
- Light Sandy Clay Loam: 2.5YR 3/4;
- Sandy Clay Loam: 2.5YR 3/4;

(ex Venn, Aldrick '72)
Ref. site N.T./K2

WILLEROO
On 2.11.12 (14,.15)
soft

- Sand-Loamy Sand: 5YR 3/3;
- Sandy-Loamy Sand: 2.5YR 3/4;
- Loamy Sand: 2.5YR 3/4;
- Sandy Clay Loam: 2.5YR 3/4;
- Loam: 2.5YR 3/4;
- Clay Loam-Light Clay with Sand: 2.5YR 3/4;

(ex Venn, Aldrick '72)
Ref. site W.T./W1

RUBY
On 2.11.12
soft

- Sand to Sandy Loam: 5YR 3/3;
- Sandy Loam: 2.5YR 3/4;
- Sandy Clay Loam: 2.5YR 3/4;
- Clay Loam - Sandy Clay: 10R 3/6;

(ex Venn, Aldrick '72)
Ref. site W.T./W1

TIPPERARY
Dr 4.51,.52
loose or soft

- Sand-Loamy Sand: 5YR 3/3;
- Sandy Clay Loam: 2.5YR 3/4;
- Light Sandy Cl: 2.5YR 3/4;
- Sandy Clay Loam: 2.5YR 3/4;
- Sandy Clay: 2.5YR 3/4;
- Clay Loam: 10R 3/6;
- Clay: 10R 3/6;

(ex Blain, Aldrick '72)
Ref. site K.T./K2
Figure 6: Particle size information and appropriate boundaries of the Blain sandy surfaced red earths (18 profiles).
contents and consequently the highest nutrient status and available water capacities of all earth soils of the Daly Basin.

For the soils grouped within the Tippera family in the revised classification Aldrick (1972) described eleven soil series: three each for the Ooloo, Tippera and Tindall families and two for the Emu family. Collated particle size results of soils from different areas show distinct geographic/geomorphic groups, (i.e. the Ooloo, Katherine, Hayes Creek, Tipperary/Fish River and Fenton). Consequently, locations best representing the soil profile classes have been chosen as the name whenever possible. On current data the revised classification distinguishes six profile classes of the Tippera family. These have been named the Ooloo, Kintore, Hayes, Emu, Fenton and Tindall soil profile classes. We wish to stress that similar soils to these occur quite extensively to the south of what is considered the Daly Basin and as more information becomes available from these areas, it is likely that further profile classes will be added to the Tippera family (e.g. Sunday Creek and Gorrie). Current soil profile classes are presented diagramatically in Figure 7 and are also briefly described. The overall particle size trends of the family are shown in Figure 8.

The lightest textured member of the Tippera family is the Ooloo soil profile class, which was described by Aldrick (1972) as a sandy red earth. It has a sandy loam or sandy clay loam surface, a sandy clay loam immediate subsurface and field textures of clay loam or light clay at depth (1.5m). An example of this soil is the Airstrip Block on Garabaldi (Douglas-Daly). There appears to be two soils which fall into the Oooloos. One has a fine sand component presumably associated with the Ooloo sediments. The other has coarse surface possibly associated with Mullaman material.

The Kintore profile class represents the model Tippera as per Aldrick (1972) with a sandy clay loam surface to light/medium clay at depth as found on Hickeys Farm at Katherine. In 1972, Aldrick described a Tippera hydromorphic series (2 and 3). In this classification this is the Hayes soil profile class. Textures are similar to Kintore however, the B horizon has few to many mottles.
Figure 7: Representative profile classes of Tippera loamy surfaced red earths.

GULLO
Gn 2.1, Un 4.21
hard setting

Sandy Loam-Sandy Clay Loam:
SYR 3/3;

Sandy Clay Loam-Fine Sand Clay Loam:
SYR 3/4-6;

Fine Sandy Clay Loam-Light Clay (sandy):
2.5YR-10R 3/4-3/6;

(ex Gulloo 1+2, Aldrick '72)
Ref. site N.T./11

KINTORE
Gn 2.11, 12
hard setting

Sandy Loam-Clay Loam:
SYR 3/3; <5% grav

Clay Loam:
SYR 3/4; <5% grav

Light Clay:
2.5YR 3/4; <10% grav

Light Medium Clay:
2.5YR-10R 3/4-3/6; <10% grav

(ex Tippera 1, Aldrick '72)
Ref. site N.T. E/3

HAYES
Gn 2.11, 12, 14, 15
hard setting

Fine Sandy Loam-Clay Loam:
10R-2.5R 3/3; <5% grav

Clay Loam-Light Clay:
7.5YR-4/4; <10% grav

Light Clay:
7.5YR-4/4; <10% grav

Light Medium Clay:
5YR 4/4; <10% grav

<10% red and yellow mottles

<20% red-yellow mottles

<10% Mn concretions, clay skins

(ex Tippera 1+2, Aldrick '72)
Ref. site N.T./D4
Figure 7: Continued

**EMU**
On 2.11(.14)
hard setting

- Fine Sandy Loam-Fine Sandy Clay Loam: 7.5YR 3/2;
- Fine Sandy Clay Loam-Clay Loam (fine sandy); 5YR-2.5YR 3/4;
- Light Clay (fine sandy) - Silty Clay: 2.5YR 3/4;
- Light Medium Clay - Silty Clay: 10R 3/4;

(by Esw 1+2, Aldrick '72)
Ref. site N.T./T2

**FENTON**
On 2.11,12,3-11,13(.14)
hard setting

- Sandy Clay Loam-Clay Loam: 2.5YR 3/3;
- Light Clay: 2.5YR 3/4;
- Light Medium Clay: 2.5YR-10R 3/4;
- Medium Heavy Clay: 10R 3/4-3/6;
- Weak angular blocky structure

(by Tindall 1A, Aldrick '72)
Ref. site N.T./D6; N.T./K4

**TINDALL**
On 3.11,12 (On 2.11,12)
hard setting

- Sandy Loam-Clay Loam
- Sandy Clay Loam-Light Medium Clay
- Clay Loam-Light Medium Clay
- Light Clay-Heavy Clay: 10R 3/4;

Moderate to well developed angular blocky structure and textural change often in bands

(by Tindall 1A, Aldrick '72)
Figure 8: Particle size information and approximate boundaries of Tippera loamy surfaced red earths (54 profiles).
and ferromanganiferous gravels. These soils are common adjacent to drainage lines and an example is Paddock D1 on Kumbychants (Douglas-Daly).

The Emu profile class includes the soils previously described by Aldrick (1972) as the Emu family. They have similar field textures as the Kintore soil profile class except there is an obvious 'fluffy' fine sand and/or silt component. They are named after Emu Spring on Tipperary Station where they are particularly widespread.

The heaviest red earth soils of the Basin are contained within the Fenton profile class. They generally have clay loam surfaces and medium to heavy clay subsoils with many clay skins, as well as some structural development. They include the Tippera type profile of Stewart (1956) and Tindall 1(b) of Aldrick (1972). Representative soils are located at the CSIRO Katherine 4 Mile Farm and paddocks S2, D2 and D3 on Ceres Downs and Kumbychants, respectively (Douglas-Daly). The sixth member, the Tindall profile class, describes the heavy textured Tippera soils described by Aldrick (1972) which have obvious banding of structural subsoil material. These occur on the fringe of the Basin where the Tindall sediments are very thin, as on Tipperary and Jindare Stations.

Regional trends are quite evident within the Tippera soils, with the major differences being in clay contents and in the ratio of fine sand to coarse sand (Figure 9). These appear to collate well with regional geology. For example, the Fenton and Tindall soils are generally located on the eastern and western borders of the Basin on the Tindall formation. The Emu soils, with the highest silt and fine sand component, are most abundant on the Jinduckin sediments and are best expressed on Tipperary and Fish River Stations. The Ooloo soils are generally associated with Ooloo sediments, which are more centrally located within the Basin.
Figure 9: Particle size information for profile classes of the Tippera family.

(1) Ooloo profile class (15 profiles)

(2) Krec profile class (3 profiles)
Figure 9: Cont'd.

(3) Emu profile class (14 profiles)

(4) Hayes profile class (11 profiles)
Figure 9: Cont’d.

(5) Fenton profile class (12 profiles)

(6) Tindall profile class (3 profiles)
4. DESCRIPTION OF YELLOW EARTH SOIL FAMILIES

Yellow earths are almost exclusively gradational (Gn) soils. These soils must have a yellow subsoil (value/chroma of 4; Northcote et al. 1975) although surface colours are usually dark greyish browns. They generally have an unbleached A2 horizon, are massive and earthy throughout, with slightly acid to neutral reaction trends. The maximum texture of the subsoil by 1.5 m must be heavier than light sandy clay loam.

Although some yellow earths have properties similar to red earths, the majority tend to show a greater textural gradient from the surface. They also contain many more gravels, nodules and mottles, and lack the structural development that exists in some of the heavy textured red earths.

The soils described in this section have previously been classified as yellow earths, yellow podzolics, lateritic podzolics and alluvial red earths (Aldrick 1972). To date the classification of these soils has proved the most troublesome of any group. Set out below is a summary of relevant soil classification to date, and the reasoning behind the restructuring. A description of the families and profile classes grouped as yellow earths under the revised classification is also presented.

4.1 Review of previous classification

Stewart (1956) initially described these soils as yellow and lateritic podzolic soils but as van de Graaff (1965, P.74) commented, they differed from those described by Stephens (1953) by being '....mainly gradational without sharply defined colour or structural horizons'.

van de Graaff (1965) described only three families of yellow earths: the Elliott (previously Elliott Creek), Elizabeth and Cullen families. Both van de Graaff (1965) and later Aldrick (1972), described the Elliott family as having similar textures to the Tippera family, with the exception of having mottled and commonly
gravelly subsoils. They also lacked the structure that may occur in some heavier red earths. However, van de Graaff (1965, P.75) also included in the Elliott family 'some soils with surface textures finer and coarser than is characteristic,... (sandy loam to sandy clay loam).... such as clays and sand when they conformed with other properties.' He recorded 107 Elliott profiles across the survey area, compared to 123 Tippera profiles. This ratio (0.9:1) conflicts with the accent of more recent work in the Daly Basin (0.1:1). In reviewing van de Graaff's classification, it appears that many of the soils classified as yellow podzolics by more recent workers (Aldrick 1972; Lucas and Sivertsen 1983) would have been classified as Elliott soils by van de Graaff (1965) (Table 5).

Stewart (1956) described a Florina soil family which he included in the lateritic podzolic soils. van de Graaff (1965) described the Florina family as a sandy brown earth (as per Stephens 1953), but allowed a wider range of A horizon textures and horizon depths than outlined by Stewart (1956). Aldrick (1972) considered that much confusion had arisen as a result of the broadness of the range of the profile characteristics of the previously described Florina, and subdivided his interpretation of the Florina into five families. These being the Florina, Ejong, Douglas, Jindare and Claravale families (yellow podzolics and lateritic podzolics). It is considered that the latter family descriptions overlap and contradict earlier work.

Following reference to van de Graaff (1965, Table 8) and Aldrick (1972, P.40), it was concluded that Aldrick allowed a much narrower range of profile characteristics within the Elliott family than that originally described by van de Graaff (1965). As a consequence, it is felt that soils described by Aldrick (1972) as Elliott, Ejong, Florina and Douglas families were covered by van de Graaff's (1965) description of an Elliott soil family.

Furthermore, the lateritic podzolic Jindare and Claravale families first described by Aldrick (1972) were accommodated previously by van de Graaff (1965) under the Florina sandy brown earth family. Hence, the Florina as described by Aldrick (1972) is not consistent...
with that described by Stewart (1955, 1956) and van de Graaff (1965). This pathway in the soil family nomenclature is shown in Table 5.

In maintaining the analogy between the Elliott and Tippera soil families descriptions of an Elliott and yellow earths in general have become too rigid. Stace et al. (1968) describe the occurrence of 'a few to many nodules below 30 to 45 cm' in yellow earths, as well as 'a (podzolic) form, more common in higher rainfall areas, with a weakly developed paler A2 horizon above a yellow subsoil'. Aldrick (1972) considered that these features represented sufficient evidence to classify these such soils in the podzolic Great Soil Groups. The authors wish to base this classification as far as possible on soil morphology rather than on inferences of genesis. As these profiles are earth soils rather than podzolics, they can be accommodated as a 'podzolic form' of a yellow earth (Stace et al. 1968). However, it is considered that Aldrick's description of a Florina has been widely adopted and should be followed. Hence such soils are described as the Florina profile class of the Elliott family.

Furthermore, it was thought that the paler and more 'duplex like' soils classified as podzolics by Aldrick (1972) could be classified as grey earths according to Coventry and Fett (1982). However, a review of previous descriptions of such Daly Basin soils revealed most upper B horizon colours to be predominantly yellow and the soils to be yellow earths. Nevertheless, some of these soils did meet the criteria of Northcote et al. (1975) for the grey massive earths.

4.2 Proposed classification

The revised classification recognises three families of yellow earths, being the fine loamy levee yellow earths, (as yet unnamed), the Elliott loamy surface yellow earths and the Jindabeth nodular...
TABLE 5: Historical and proposed classification of yellow earthy sands and yellow earths of the Daly Basin.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G.S.G. *</td>
<td>G.S.G. *</td>
<td>G.S.G. *</td>
<td>G.S.G. #</td>
</tr>
<tr>
<td>Family</td>
<td>Family</td>
<td>Sub-Group</td>
<td>Family</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Red</td>
<td>Alluvial</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td>Alluvial</td>
<td>Red</td>
<td>Edith II</td>
<td>loamy levee</td>
</tr>
<tr>
<td>Yellow</td>
<td></td>
<td></td>
<td>(unnamed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateritic</td>
<td>Florina</td>
<td>Claroavite</td>
<td>Jindare</td>
</tr>
<tr>
<td>Podzollics</td>
<td>Sandy</td>
<td>Earthy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brown</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cullen</td>
<td>Florina</td>
<td>Jindare</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td>Elliott</td>
<td>Normal</td>
<td>Elliott</td>
</tr>
<tr>
<td>Podzollics</td>
<td>Creek</td>
<td>Sandy</td>
<td>Fleming</td>
</tr>
<tr>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

G.S.G. * Great Soil Group (Stephens 1953)  G.S.G. # Great Soil Group (Stace et al. 1968)
sandy surface yellow earths (Table 5). Claravale soils have predominantly uniform, coarse textures so they are earthy sands rather than earths.

Previously Stewart (1956), van de Graaff (1965) and Aldrick (1972) have not designated 'alluvial' soils as being yellow earths. However, Aldrick (1972) described subsoil colours of alluvial red earths as varying from dark reddish brown to yellowish brown. He included these yellower soils with the alluvial red earths because of their common parent material and mode of origin, providing separate soil profile classes for the yellower, less well drained soils, (i.e. the Edith Series II and the Belbowie Series II). These soils are often located on levees adjacent to large backplains. To date, little information has been collected on these soils. Only a single family/profile class is presently recognised, consisting of the profile description for the Belbowie soil profile classes II of Aldrick (1972) which has been left unnamed (Figure 10).

However, current studies being undertaken adjacent to the Katherine River are expected to allow more adequate classification in the near future.

**Elliott family**

Some characteristics of the Elliott family are summarised in Table 6.

The Elliott loamy yellow earth family has been broadened making it more like the original Elliott described by van de Graaff (1965). It now includes the Ejong family (Aldrick 1972) and most of the yellow podzolics described by Aldrick (1972).
Figure 10: Descriptions of 'alluvial' family/profile class previously described as Edith 2 and Belbowie 2 (Aldrick, 1972). Yellow earths - (unnamed) fine loamy levee soils

**Drainage:** Moderately well drained

**Parent Material:** River alluvial, deposited by annual floods.

**Showing:**

- Dark brown (10YR 4/3), dark yellowish brown (10YR 4/4) or rarely very dark brown (10YR 2/1) or 20-30 cm thick loam to clay loam, slightly hard, earthy fabric; pH 6.0-6.5.

- Dark yellowish brown (10YR 4/4), yellowish brown (10YR 5/3) or strong brown (7.5YR 5/4) or very dark brown (10YR 5/5), 5-10 cm thick loamy sand or sandy clay loam or very dark brown (10YR 2/1) or very dark brown (10YR 4/1), 5-10 cm thick clay loam or slightly clay loam, hard, earthy fabric; pH 6.0-7.0. Some 1-2 cm thick reddish brown concretion of soil material and common red or yellowish mottles.

- Very dark greyish brown (10YR 4/2), dark reddish brown (5YR 4/2) or black (2.5YR 1/2). 5-10 cm thick organic clay loam, hard or very hard, earthy fabric; pH 6.0-7.0.

- Dark brown (7.5YR 4/4), clay loam or light clay, hard or very hard, earthy fabric; pH 6.0-7.0. The horizon may be a weak weathered A2.

- Yellowish brown (10YR 5/4) or strong brown (7.5YR 5/4) or light grayish brown (10YR 6/4) very hard or very hard, earthy fabric with some clay skins; pH 6.0-7.0. Brown reddish mottles may occur.

- Yellowish brown (10YR 5/6) or 5.0 light or medium clay, very hard or very hard; earthy fabric with some clay skins; pH 6.0-7.0. Reddish mottles and clay skins are common.

The poorly drained phase has common white mottling, with some reddish brown or grayish mottles extending to the soil surface. The lower parts of the profile contain many clay skins and have some smooth-surfaced fabric. Subsoil permeability is low. These soils are often similar to those of Marrakai family.
Figure 11: Representative profile classes of Elliott loamy surfaced yellow earths.
Figure 12: Particle size distribution boundaries of Elliott loamy surfaced yellow earths (5 profiles).
Three profile classes have been described and are presented in Figure 11. These are the King, Flemming and Florina classes. Texturally, the King and Flemming are similar to the Hayes class of the Tippera family. However, the yellow earths tend to be more mottled, shallower and more gravelly. The Florina profile class is the podzolic form, having an A2 horizon and an intensely mottled B horizon often associated with illuviated clay. It includes many of the soils previously described as yellow podzolics by Aldrick (1972). The King profile class is characteristically very gravelly, whereas the Flemming soil profile classes has less gravels but is mottled. Particle size data for the Elliott family soils are shown in Figure 12. These soils are thought to be derived from similar parent material as the red earths (Aldrick 1972) but under less well drained contemporary conditions.

Jindabeth family

Characteristics of the Jindabeth family are outlined in Table 6. The Jindabeth nodular sandy yellow earth family consists of soils of the Elizabeth family, (as described by van de Graaff (1965)), the Jindare family and some of the Claravale and Douglas families (Aldrick 1972).

The Elizabeth and Jindare profile classes have been identified within the Jindabeth family. Both van de Graaff (1965) and Aldrick (1972) commented that the Elizabeth soil was approximately similar in texture to a Blain soil, although they did not concur on the amount of gravel contained in the profile or the origin of the parent material. Elizabeth soils are not common and Aldrick (1972) only described a single series. More common are the gravelly Jindare soils, first described by Aldrick (1972) but previously encompassed by the Florina family of Stewart (1956) and van de Graaff (1965).
### TABLE 6: Summary of characteristics of the Elliott and Jindabeth family soils (yellow earths).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Elliott Family</th>
<th>Jindabeth Family</th>
<th>Claravale Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>Variable (2-5a).</td>
<td>Variable (1-5 c).</td>
<td></td>
</tr>
<tr>
<td>Horizon Boundaries</td>
<td>Gradual (no bleached A2).</td>
<td>Gradual or diffuse except for a darker surface and weak A2 horizon.</td>
<td>Gradual or diffuse except for a darker surface and weak A2 horizon.</td>
</tr>
<tr>
<td>Reaction</td>
<td>Neutral to slightly acid.</td>
<td>Neutral to slightly acid.</td>
<td>Neutral to slightly acid.</td>
</tr>
<tr>
<td>Gravel Content</td>
<td>A HORIZON - generally few ferromanganeseous gravels but increasing with depth commonly to 20% and sometimes higher.</td>
<td>Variable, subsoil gravelly (20-60%) being ferriginous or ferriginated sandstone.</td>
<td>Variable, subsoil gravelly (20-80%) being ferriginous.</td>
</tr>
<tr>
<td>Drainage</td>
<td>Moderately well to poor, subsoils mottled (common to many).</td>
<td>Moderately well to poor, subsoils mottled (common to many).</td>
<td>Moderately well to well drained.</td>
</tr>
<tr>
<td>Surface</td>
<td>Up to clay loam (but often lighter).</td>
<td>Sand to light sandy loam.</td>
<td>Sand to loamy sand.</td>
</tr>
<tr>
<td>Subsoil (1.5m)</td>
<td>Light clay or heavier.</td>
<td>As heavy as sandy clay or heavy clay where illuviated clay has been concentrated.</td>
<td>Sandy loam. Shallow, very gravelly phases may occur in areas dominated by laterite.</td>
</tr>
<tr>
<td>Surface Consistence</td>
<td>At least very firm (hard-setting).</td>
<td>Loose to moderately firm (weakly hard-setting).</td>
<td>Loose to moderately firm (weakly hard-setting).</td>
</tr>
</tbody>
</table>
Soils of the Elizabeth profile class have a loamy sand surface gradually increasing to a light the clay at depth (1.5 m). Jindare soils have similar textures to Elizabeth soils but the clay increase with depth is more rapid and they also have greater amounts of gravel throughout the profile. Elizabeth soils are moderately well drained whereas Jindare soils are imperfectly or poorly drained. Typical profile descriptions of these two profile classes are shown in Figure 13.

Very little analytical data is available for these soils, and what is available is only from the north of the Daly Basin. Particle size data has not been presented for this family.

Parent material is probably colluvial accumulations or alluvial outwash fans of transported detrital laterite, ferruginised arenaceous sediments and weathered pallid zone material (Aldrick 1972).

Claravale nodular earthy sands

Table 6 outlines properties of the Claravale soils.

Soils previously described as belonging to the Claravale family (Aldrick 1972) are now classified as yellow earthy sands.

Little data is available for this group of soils and they have not been subdivided. A typical profile description is shown in Figure 13 and has been given the name Claravale.

Parent material is probably colluvial accumulations or alluvial outwash fans of transported detrital laterite and weathered pallid zone material (Aldrick 1972).
Figure 13: Representative profiles for the Jindare and Elizabeth profile classes of the Jindabeth family and for the Claravale family.

**JINDARE**

- **Go 2 or by surface gravel (to 50%)**
  - Sand-Light Sandy Loam: 10YR 3/2-4/2; 10% Fe.
  - Loamy Sand-Sandy Loam: 10YR 5/6-6/3; 15-30% Fe.
  - Light Sandy Clay Loam: 7.5YR-10YR 5/6-6/6; < 30% Fe.
  - Sandy Clay Loam-Light Clay: 7.5YR 5/6-5/8; 10% Fe.
  - many red and brown mottles, illuvial clay.
  - heavy clay over siltstone (mainly Jindare, Aldrick '72)

**ELIZABETH**

- **Go 2.2**
  - Sandy Loam: 7.5YR-10YR 5/6-6/8.
  - Sandy Clay Loam-Light Clay: 7.5YR 5/6-5/8; 10-20% Fe.
  - Sandy Clay Loam-Light Clay: 7.5YR 2.5YR 5/6-5/8; 30% Fe.
  - common red and yellow mottles (Elizabeth, Aldrick '72)

**CLARAVALE**

- **Go 4.2**
  - Loamy Sand: 10YR 3/2-4/3; 0-50% Fe.
  - Sand-Loamy Sand: 10YR 5/4-6/6 (6/3); 5-50% Fe.
  - Clay Sand; (1)Sandy Loam: 7.5YR-10YR 5/5-6/6; 10-60% Fe.
  - dense gravels (50-90%) in weathered CR matrix or strongly weathered laterite or sandstone.
  - (mainly Claravale, Aldrick '72)
5. DESCRIPTION OF GREY EARTH SOIL FAMILIES

Grey earths are predominantly Gn soils, with Dg profiles being less common. Soils must have a grey subsoil (value/chroma 2 or 3; Northcote et al. 1975). Profiles are generally massive and earthy throughout but may show sandy surface fabric or some degree of structural development in subsoils with high clay contents. The texture of the subsoil must be light sandy clay loam or heavier by 1.5 m.

5.1 Review of previous classification

Neither Stace et al. (1968) nor Stephens (1953) recognised 'grey earths' as described by Northcote et al. (1975). Consequently, soils grouped as such have not been previously described in reports of the Daly Basin.

Stewart (1956) described many soil horizons as grey or grey-brown. However, he did not use Munsell colour nomenclature and did not indicate whether moist or dry colours were taken. van de Graaff (1965) classified the Florina family as a sandy brown earth. He described it with an A$_3$/B$_1$ horizon being 'a light shade of brown or yellowish brown'.

The descriptions of yellow podzolics, lateritic podzolics and gleyed podzolics (Aldrick 1972) include a number of profiles with pale colours. The majority of these are either Uc profiles or have yellowish brown moist colours and do not meet the colour criterion of Northcote et al. (1975) for a grey massive earth. However colours used by Aldrick (1972) to describe soils of the Florina soil profile classes II, and some of the Douglas, Claravale and Marrakai profile types do meet the criteria. More soils could be placed in this group if the criterion* proposed by Coventry (1982) was adopted.

* Includes soils that meet the requirements of the yellow but are predominantly grey in colour. The soil colour names employed are those of Coventry and Robinson (1981). As such they are grey massive earths (Northcote et al. 1975), as well as similar soils with either uniform or weakly developed duplex profiles.
It is the view of the authors that grey earths in the Daly Basin may not be common but should be included in the classification. As very little data is available for these soils, major change was considered undesirable.

However, it was considered necessary to illustrate some initial breakdown. Consistent with the red earths and yellow earths classification, the grey earths have been initially subdivided into two families and the basis of A and B horizon texture. A summary of the main characteristics of the two grey earth families (Douglas and Marrakai) is set out in Table 7 below. Further subdivision into profile classes has not been undertaken and the descriptions of Aldrick (1972) are presented to represent this group of soils (Figure 14).
Table 7: Summary of the main characteristics of the Douglas and Marrakai family soils (grey earths).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Douglas Family</th>
<th>Marrakai Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>Depth (up to 1.5m)</td>
<td>Deep (up to 1.5m)</td>
</tr>
<tr>
<td>Structure</td>
<td>Massive and earthy throughout, some sandy surfaces.</td>
<td>Massive and earthy throughout, may have weak structured B horizons.</td>
</tr>
<tr>
<td>Colour</td>
<td>A horizon - dark grey; B horizon - pale brown or light yellowish brown.</td>
<td>A horizon - very dark grey to dark greyish brown; B horizon - brown to light yellowish brown.</td>
</tr>
<tr>
<td>Profile development</td>
<td>Moderate - A₂ horizons present not bleached.</td>
<td>Moderate - A₂ horizons not usually bleached.</td>
</tr>
<tr>
<td>Horizon boundaries</td>
<td>Generally gradual or diffuse, but may be abrupt.</td>
<td>Gradual or diffuse boundaries.</td>
</tr>
<tr>
<td>Reaction trend</td>
<td>Neutral to slightly acid throughout.</td>
<td>Neutral to slightly acid throughout. May have carbonate in lower B horizon.</td>
</tr>
<tr>
<td>Drainage</td>
<td>Imperfect or poorly drained.</td>
<td>Poorly drained.</td>
</tr>
<tr>
<td>Texture</td>
<td>Gradational or duplex profiles - conspicuous medium-sized sand throughout.</td>
<td>Gradational profiles.</td>
</tr>
<tr>
<td>Surface</td>
<td>Sand or loamy sand.</td>
<td>Sandy loam to silty clay loam.</td>
</tr>
<tr>
<td>Immediate sub-surface</td>
<td>Loamy sand.</td>
<td>(Silty) clay loam.</td>
</tr>
<tr>
<td>(10-30cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsoil (1.5m)</td>
<td>Sandy clay.</td>
<td>Silty clay, light to medium clay.</td>
</tr>
<tr>
<td>Surface consistence</td>
<td>Loose or moderately weak.</td>
<td>At least very firm.</td>
</tr>
</tbody>
</table>
Figure 14: Typical profiles for the grey earths (as per Aldrick 1972)

**DRAINAGE:** Imperfectly or very poorly drained

**PARENT MATERIAL:** Local sandy alluvia or colluvia, or sandy river alluvia. Drainage line or river backplain soils.

### Typical Profiles

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Soil Type</th>
</tr>
</thead>
</table>
| 0-20      | Very dark greyish brown (10YR 3/2), dark grey (10YR 4/1) or greyish brown (10YR 4/3) sand or loamy sand, sandy clay loam, brown or yellowish brown (5YR 4/2) clay loam or sandy clay, very hard or medium firm; earthy fabric; pH 5.5-6.5. |}
| 0-20      | Pale brown (10YR 6/3), yellowish brown (10YR 6/3) or greenish brown (10YR 5/2) clay, clayey sand, silty clay loam, light brown (7.5YR 5/4) or yellowish brown (10YR 5/6) sandy clay loam, very hard or medium firm; earthy fabric; pH 5.5-6.5. |}
| 0-20      | Pale brown (10YR 6/3), yellowish brown (10YR 5/6), light brown (10YR 3/2) or greyish brown (10YR 4/3) sand, sandy clay loam, silty clay loam, slightly hard or hard; earthy fabric; pH 3.5-5.5. From 2-15cm, fine-grained concretions occur in the soil and 10-20% on the soil surface. |}
| 0-20      | Light yellowish brown (10YR 5/3), pale brown (10YR 6/3) or yellowish brown (10YR 6/3) or yellowish brown (10YR 5/6) or light brown (7.5YR 6/4) sandy clay loam or light sandy clay, very hard or medium firm; earthy fabric; pH 5.5-6.5. This horizon is commonly met with red, yellow and grey and sometimes contains a few fine-grained concretions. |}
| 0-20      | Light yellowish brown (10YR 5/6), greyish brown (10YR 6/4) or yellowish brown (10YR 6/4) sandy clay loam or sandy clay, very hard or medium firm; earthy fabric; pH 3.5-5.5. From 15-50cm, fine-grained concretions and some grey or yellow mottles. |}
| 0-20      | Light brownish grey (10YR 6/2) or yellowish brown (10YR 5/3) or yellowish brown (10YR 5/4) or light brown (7.5YR 4/3) sandy clay or medium clay, extremely hard; earthy fabric; some smooth faces; pH 4.5-5.5. From 5-10cm, fine-grained concretions and many red, yellow and brown mottles occur. This material contains illuvial clay, has a very slow permeability and often looks like soft bire. |}
| 0-20      | Brown (10R 5/3), light brownish grey (10YR 6/2) or light yellowish brown (10YR 6/4) or yellowish brown (10YR 5/4) or light brown (7.5YR 4/3) clay, clayey sand, sandy clay, very hard, earthy fabric; pH 5.5-6.0. Common red, brown, grey and yellow mottles. |}
| 0-20      | Yellowish brown (10YR 5/4), brownish yellow (10YR 5/4) or light brown (7.5YR 4/3) or clay or clayey sand, very hard, earthy fabric; pH 2.5-3.0. Common grey and yellow mottles. This horizon becomes an impermeable basal.
6. REFERENCES


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Daly1 55