LAND CAPABILITY ASSESSMENT FOR DRYLAND ANNUAL CROPPING

Proceedings of a Workshop
Australian Soil and Land Resources Committee
a technical committee of the
Standing Committee on Soil Conservation.
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

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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 co-operation 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.
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 1.5m. 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).
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<td>42.0</td>
<td>34.0</td>
<td>28.0</td>
<td>24.0</td>
<td>20.0</td>
<td>34.1</td>
</tr>
<tr>
<td>Evaporation (mm)</td>
<td>325.0</td>
<td>285.0</td>
<td>220.0</td>
<td>190.0</td>
<td>115.0</td>
<td>50.0</td>
<td>70.0</td>
<td>95.0</td>
<td>135.0</td>
<td>180.0</td>
<td>255.0</td>
<td>295.0</td>
<td>220.5</td>
</tr>
</tbody>
</table>
# TABLE 2

**RAINFALL DECILES (mm)**

**KIMBA 1920 - 1970**

<table>
<thead>
<tr>
<th>Decile</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest on Record</td>
<td>53</td>
<td>163</td>
<td>75</td>
<td>103</td>
<td>112</td>
<td>130</td>
<td>128</td>
<td>84</td>
<td>99</td>
<td>117</td>
<td>134</td>
<td>97</td>
<td>581</td>
</tr>
<tr>
<td>Decile 9</td>
<td>32</td>
<td>59</td>
<td>41</td>
<td>53</td>
<td>68</td>
<td>71</td>
<td>77</td>
<td>71</td>
<td>70</td>
<td>64</td>
<td>51</td>
<td>44</td>
<td>507</td>
</tr>
<tr>
<td>Decile 8</td>
<td>27</td>
<td>43</td>
<td>25</td>
<td>41</td>
<td>60</td>
<td>56</td>
<td>55</td>
<td>58</td>
<td>53</td>
<td>49</td>
<td>39</td>
<td>35</td>
<td>425</td>
</tr>
<tr>
<td>Decile 7</td>
<td>22</td>
<td>27</td>
<td>18</td>
<td>33</td>
<td>54</td>
<td>48</td>
<td>50</td>
<td>53</td>
<td>43</td>
<td>32</td>
<td>29</td>
<td>25</td>
<td>386</td>
</tr>
<tr>
<td>Decile 6</td>
<td>16</td>
<td>23</td>
<td>12</td>
<td>25</td>
<td>39</td>
<td>41</td>
<td>40</td>
<td>46</td>
<td>36</td>
<td>26</td>
<td>24</td>
<td>19</td>
<td>366</td>
</tr>
<tr>
<td>Decile 5</td>
<td>10</td>
<td>12</td>
<td>8</td>
<td>20</td>
<td>28</td>
<td>34</td>
<td>37</td>
<td>41</td>
<td>32</td>
<td>22</td>
<td>19</td>
<td>14</td>
<td>338</td>
</tr>
<tr>
<td>Decile 4</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>12</td>
<td>23</td>
<td>28</td>
<td>34</td>
<td>39</td>
<td>26</td>
<td>19</td>
<td>14</td>
<td>9</td>
<td>293</td>
</tr>
<tr>
<td>Decile 3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>9</td>
<td>17</td>
<td>22</td>
<td>28</td>
<td>35</td>
<td>18</td>
<td>12</td>
<td>11</td>
<td>8</td>
<td>280</td>
</tr>
<tr>
<td>Decile 2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>12</td>
<td>18</td>
<td>23</td>
<td>23</td>
<td>13</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>248</td>
</tr>
<tr>
<td>Decile 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>11</td>
<td>20</td>
<td>16</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>209</td>
</tr>
</tbody>
</table>

| Lowest on Record | 0   | 0   | 0   | 0   | 3   | 1   | 10  | 7   | 4   | 0   | 0   | 0   | 194  |

| Average | 14  | 24  | 15  | 24  | 36  | 38  | 42  | 42  | 34  | 28  | 24  | 20  | 341  |

< 14 >
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

Accumulated Daily Max. Temp °C

<table>
<thead>
<tr>
<th></th>
<th>Sowing to:</th>
<th>Optimum weekly max. temp. for flowering °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Begin</td>
<td>End</td>
</tr>
<tr>
<td></td>
<td>Tillering</td>
<td>Flowering</td>
</tr>
</tbody>
</table>

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1040</td>
<td>1900</td>
<td>2200</td>
<td>3300</td>
<td>23</td>
</tr>
<tr>
<td>Barley</td>
<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></td>
<td>1600</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></td>
<td>1600</td>
<td>2600</td>
<td>3900</td>
<td>32</td>
</tr>
<tr>
<td>Determinate</td>
<td></td>
<td>2100</td>
<td>3800</td>
<td>4200</td>
<td></td>
</tr>
</tbody>
</table>

Values vary ± 200°C depending on variety.

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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Day °C - Degree Max. Temp °C - 5.0 (sowing day of year)</td>
</tr>
<tr>
<td>Lupins</td>
<td>Day °C - Degree Max. Temp °C - 4.4 (sowing day of year)</td>
</tr>
<tr>
<td>Site</td>
<td>Soil</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
</tr>
<tr>
<td>Wanbi</td>
<td>0-60</td>
</tr>
<tr>
<td></td>
<td>60-120</td>
</tr>
<tr>
<td>Taragoro</td>
<td>0-60</td>
</tr>
<tr>
<td></td>
<td>60-120</td>
</tr>
<tr>
<td>Minnipa</td>
<td>0-60</td>
</tr>
<tr>
<td></td>
<td>60-120</td>
</tr>
<tr>
<td>Maitland</td>
<td>0-60</td>
</tr>
<tr>
<td></td>
<td>60-120</td>
</tr>
<tr>
<td>Gladstone</td>
<td>0-60</td>
</tr>
<tr>
<td></td>
<td>60-120</td>
</tr>
<tr>
<td>Turrettfield</td>
<td>0-60</td>
</tr>
<tr>
<td></td>
<td>60-120</td>
</tr>
<tr>
<td>Manoora</td>
<td>0-60</td>
</tr>
<tr>
<td></td>
<td>60-120</td>
</tr>
<tr>
<td>Salter Spr.</td>
<td>0-60</td>
</tr>
<tr>
<td></td>
<td>60-120</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, saturated 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\(^{-1}\)mm 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 1A - 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 resources 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 — Collarenbri — 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 50-60-100 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 retitie 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, tyne 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>
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<th>Time</th>
<th>Activity</th>
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Forest basalts

Scrubby basalts

Lunch

Sandstone areas

Red soils

Refreshments
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 identifiable 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 cropspecific 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 5°C.

2. The growing period commences when precipitation equals or exceeds half potential evapotranspiration ($P_{1} > 0.5$ PET).

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 5°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, consistence (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>
<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 moist</td>
<td>Loose, very 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

- \( A \) = soil loss (t/ha/year)
- \( R \) = rainfall erosivity
- \( K \) = soil erodibility
- \( L \) = slope length factor
- \( S \) = slope gradient factor
- \( C \) = crop management factor
- \( P \) = 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 subtropics (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,

\[
\text{Index of Crusting} = \frac{15Zf + 0.75Zc}{C + (10 \times OM)}
\]

where

- \(Zf\) = fine silt, %
- \(Zc\) = 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>CLASS</th>
<th>SOIL PROPERTY</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pedality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15cm</td>
<td>Apedal (sands), Coarse crumb or granular; moderate coarse angular blocky; weak platy or strong prismatic; apedal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fine crumb or granular; medium subangular blocky; platy or weak prismatic; apedal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subangular or weak prismatic; apedal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blocky blocky</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consistence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15cm</td>
<td>Loose or very friable moist firable to Firm to very Extremely firm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>moist</td>
<td>slightly firm moist, moist, hard to extremely hard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>slightly</td>
<td>extremely hard</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>hard dry</td>
<td>dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Susceptibility to surface sealing</td>
<td>None</td>
<td>Slight</td>
<td>Moderate</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td>Coarse gravel % surface cover</td>
<td>3-15</td>
<td>15-40</td>
<td>40</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 (Gibbons, 1961). 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*

<table>
<thead>
<tr>
<th>SURVEYS OF LAND RESOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soils</td>
</tr>
<tr>
<td>Landforms</td>
</tr>
<tr>
<td>Climate (agroclimatology)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SURVEYS OF LAND USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present land use</td>
</tr>
<tr>
<td>Present agricultural systems incl. crop performance etc.</td>
</tr>
<tr>
<td>Agricultural infrastructure incl. facilities, extension staff, research stations etc.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECONOMIC INVESTIGATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour, availability and cost</td>
</tr>
<tr>
<td>Markets</td>
</tr>
<tr>
<td>Prices</td>
</tr>
<tr>
<td>Farm economics</td>
</tr>
<tr>
<td>Accessibility, transport systems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SOCIOLOGICAL INVESTIGATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
</tr>
<tr>
<td>Sociology</td>
</tr>
<tr>
<td>Farmer attitudes</td>
</tr>
</tbody>
</table>

* 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 5. SOIL SURVEY SCALE, OBSERVATION DENSITY AND TIME REQUIREMENT*

<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 (25-75km²)</td>
<td></td>
</tr>
</tbody>
</table>

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

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

### TABLE 6. SCALE, WORKING AREA AND GROUND DATA OF AIRPHOTOS*

<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>1 cm² on map equals (ha)</th>
<th>Mean distance between field observations at 1 per cm² (m)</th>
<th>Survey Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:5,000</td>
<td>0.25</td>
<td>50.0</td>
<td>Intensive management, Urban development</td>
</tr>
<tr>
<td>1:10,000</td>
<td>1.0</td>
<td>100.0</td>
<td>Irrigation</td>
</tr>
<tr>
<td>1:20,000</td>
<td>5.0</td>
<td>200.0</td>
<td>Agricultural extension</td>
</tr>
<tr>
<td>1:25,000</td>
<td>6.25</td>
<td>250.0</td>
<td>Project planning and management</td>
</tr>
<tr>
<td>1:50,000</td>
<td>25.0</td>
<td>500.0</td>
<td>Regional land use planning, project feasibility</td>
</tr>
<tr>
<td>1:250,000</td>
<td>(6.25 km²)</td>
<td>(2.5 km)</td>
<td>National or regional resource inventory and land use planning</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, 1961) 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 Zulkifli, 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 Cooperative 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>13.5</td>
<td>3.2</td>
<td>1.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Cost (1980 $A/km²) at $50,000/man-year</td>
<td>1800.0</td>
<td>400.0</td>
<td>140.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Cost (Western, 1978) for consultant survey converted to $A (1980)</td>
<td>900.0</td>
<td>90-180</td>
<td>45-90</td>
<td></td>
</tr>
<tr>
<td>USDA estimate at 1:20,000 scale</td>
<td>250.0</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.
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.

(i) 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 than 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>
<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 Nil to</td>
<td>The limitations of long term instability, engineering difficulties or erosion hazard do not occur or are very slight.</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>very low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Low</td>
<td>Slight limitations are present in the form of engineering difficulties and/or erosion hazard.</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 Moderate</td>
<td>Moderate engineering difficulties and/or a moderate erosion hazard exist during construction.</td>
<td>Specialised designs and installation techniques are required to minimize development impact on the environment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 High</td>
<td>Considerable engineering difficulties during development and/or a high erosion hazard exists during and after construction.</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 Severe</td>
<td>Long term severe instability hazards, erosion or engineering difficulties which cannot be practically overcome with current technology.</td>
<td>Severe deterioration of the environment will probably occur if attempted in these areas.</td>
</tr>
<tr>
<td>LAND FEATURES AFFECTING USE</td>
<td>GRADIENT</td>
<td>SOIL STRUCTURE</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Apedal-weak</td>
<td>0-4%</td>
</tr>
<tr>
<td></td>
<td>Moderate, S.G.</td>
<td>0-8%</td>
</tr>
<tr>
<td></td>
<td>Strong</td>
<td>0-15%</td>
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</tbody>
</table>

CAPABILITY CLASS:

1. Excellent
2. Good
3. Fair
4. Poor
5. Unsuitable
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.

References


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

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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 feed back 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>
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<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>Sa</td>
</tr>
<tr>
<td>shrink-swell potential</td>
<td>S1</td>
</tr>
<tr>
<td>dispersible clays</td>
<td>Sd</td>
</tr>
<tr>
<td>soluble salts</td>
<td>Sn</td>
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<tr>
<td>soil texture</td>
<td>St</td>
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<tr>
<td>organic matter</td>
<td>So</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Depth of Material</th>
<th>Symbol</th>
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</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>Bd</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>

| Slope                | G      |

| Landslip Hazard      | L      |

| Flooding             |        |
| flash floods         | FF     |
| inundation           | FI     |

| Rockiness            |        |
| rock outcrop         | Ro     |
| boulders             | Rb     |
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 sub-division, 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>CROPPING (wheat/barley/oats Rainfall &gt;450mm) 30 Jan 85</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>1 Slope (%) 0-3</td>
<td>3-5</td>
<td>5-6</td>
<td>8-12</td>
<td>12-200</td>
<td></td>
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<tr>
<td>2 Drainage W</td>
<td>MW</td>
<td>I EW</td>
<td>P</td>
<td>VP</td>
<td></td>
</tr>
<tr>
<td>4 Flooding 0-5</td>
<td>5-10</td>
<td>10-20</td>
<td>20-100</td>
<td>100-200</td>
<td></td>
</tr>
<tr>
<td>5 Depth to seas, WT 500-30</td>
<td>30-25</td>
<td>25-20</td>
<td>20-15</td>
<td>15-0</td>
<td></td>
</tr>
<tr>
<td>9 Gravel 0-1</td>
<td>1-5</td>
<td>5-10</td>
<td>10-25</td>
<td>25-100</td>
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<tr>
<td>10 Stones 0-1</td>
<td>1-5</td>
<td>5-10</td>
<td>10-25</td>
<td>25-100</td>
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<tr>
<td>11 Boulders 0-0</td>
<td>0-0.01</td>
<td>0.01-0.05</td>
<td>0.05-1</td>
<td>1-100</td>
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<tr>
<td>12 Rock Outcrop 0-0</td>
<td>0-0.01</td>
<td>0.01-0.05</td>
<td>0.05-1</td>
<td>1-100</td>
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<tr>
<td>17 Topsoil Texture SL L ORGL LS CL LFS ORGC C LC</td>
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<tr>
<td>21 Depth to Hard Rock 500-60</td>
<td>60-50</td>
<td>50-40</td>
<td>40-30</td>
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<td>18 Topsoil Depth 500-20</td>
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<td>10-8</td>
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#### ASSESSMENT TABLE

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<th>21</th>
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- 87 -
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

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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; and
- 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 1(a) zones throughout a local government area and the subsequent identification of Rural 1(c) (small holdings) and Rural 1(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 piggeries and feed lots 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 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 (e.g. a 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 (cereals, oilseeds, fodder, etc.) or intensive horticulture (vegetables, orchards). Has a very good capability for agriculture, where there is only minor or 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 cultivated for an occasional cash crop or forage crop in conjunction with pasture management. 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 lands are capable of sustained high levels of production, although conservation measures may be required.
- 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. Overall level of production is low. Environmental constraints make arable agriculture uneconomic.
- 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 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, those 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 50% (27 degrees); or in notified catchments under the Soil Conservation Act, 1938, slopes greater than 33 1/3 (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:

1. The topographic base maps.
2. It may be convenient to assemble the individual topographic maps into one large map. However, the usual practice is to map on 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 overburdened with too much detail.
- 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 resources 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 experienced officer can identify the class boundaries. LANDSAT images available from the Department of Lands often provide a suitable overview of areas under study. The 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 officers identify the capability class of uniform areas of land and the type and degree of constraints to production. These are noted on the map. Wherever 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. Whether 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", "capability drops off on salt-affected land" or "the slopes are too steep for cropping," etc.) as 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 e.g. 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;
Whenever possible, derived measures should be used as a basis for economic information can then be used as a basis for mapping or considering them in detail. The list of factors that may influence agricultural activity on agricultural land, such as poplar plantations, so that land in each class to the agriculture of the local government area. They often have information on production at the property level which could be used to refine uncertain boundaries of classifications.

The completed field map is used as the basis for the first draft of the agricultural capability map. The boundaries of the capability classes are determined from the field information and from other land resource maps that are available. Soil or geological maps could be used to assist in drawing more accurate boundaries, or yield levels can be checked using data from various sources. The resulting map will show relatively homogeneous areas with respect to agricultural capability that permit statements to be made concerning land use, management, or zones that apply to the whole of each area.

The completed map should now be discussed with the officers from the Soil Conservation Service and the Department of Agriculture involved in the field survey for checking, and their comments used to amend the map where necessary. Another valuable source of information for checking the map are the district surveyors and other officers from the Department of Lands who work in the local government area. They often have information on production at the property level which could be used to refine uncertain boundaries of classifications.

The form of a transparent overlay on the base map. This permits other maps to be overlaid in turn in order to determine conflicts and opportunities when deciding on zoning or development. The map should show the boundaries around areas of the same capability class and reference points to accurately locate the overlay onto the base map. It is also useful to have another copy of the base map onto which this information is drawn as a permanent record.

The text 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 activities, 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 in the report 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.

Formulating recommendations:

- High quality agricultural land should not be used for incompatible development when 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 an 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, bud stock or fruit 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,
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.

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.
- 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 parcels which have sustained 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 to moderately deep, well drained and have good available water capacity.
    - Climatic and environmental conditions are particularly favourable for sensitive crops whose cultivation would be seriously impaired in adjacent areas with less favourable characteristics.
    - Erosion damage or hazard is low to moderate: soil conservation measures may be required.
    - Soils have a moderate to high capability to withstand frequent cultivation and artificial irrigation without serious damage, except for those on steeper lands which have a low capability and require conservation works.
    - Soils can be maintained in good tilth and productivity.
    - For a wide range of field crops, adapted to the region, their productivity is high to moderately high.
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 because of unsuitable soil-physical properties incapable of economic amelioration.

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 wees 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 growth 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.
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 shortcomings 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 micro-fiche, 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 co-operation in the planning, conduct and application of soil and land surveys and of agronomic research

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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 compromise 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;
i) 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 ALRSC.
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