Soil and landscape constraint mapping system for land use planning

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Abstract
A series of soil and landscape constraint maps based on the relative costs of ameliorating on-site hazards as well as residual on-site and off-site risks have been developed for coastal NSW. The includes the objective ranking of multiple soil landscape qualities combined with digital elevation model technology, state-of-the-art erosion hazard modelling and Acid Sulfate Soil Risk mapping, all in a risk management setting. The resulting raster surfaces comprise 232 million pixels (25 x 25 m) and extend over 3.8 million hectares of the NSW Coast and provide unprecedented levels of spatial resolution to aid regional planning.
The results can be readily interpreted by land use planners and land managers and should contribute to environmentally sustainable land use decision making in NSW coastal regions.

Key Words
Land use planning, risk assessment.

Introduction
The effective and sustainable use of land involves a matching of site conditions with the specific requirements and potential impacts of different land uses. Significant costs to the environment and society in general may result where land is used for purposes for which it is not physically capable of sustaining. Failing to use land within its capability may have serious consequences. Common environmental impacts occurring both on and off-site include foundation instability, flooding, soil erosion and sedimentation, contamination and eutrophication of water bodies, release of acid solutions from acid sulfate soils and high maintenance costs.

In 2004 to 2006 the NSW Department of Natural Resources, working with the Department of Planning, developed a new innovative approach to capability assessment called *soil and landscape constraint assessment*.

The approach recognises the following features of land capability:

- Capability is about risk management.
- Disparate risks can be compared by assessing consequences and frequencies
- Impacts differ between land uses
- Impacts depend on site features
- Rules to assess capability can be applied on a consistent basis over large areas
- Risk and capability can be changed by human intervention
- Interventions can be costed
- Residual risks after intervention can be re-assessed.

Methods
We used the capability principles to produce a series of soil and land capability constraint maps for twelve land uses along the NSW coast. To do this we:
1) completed, digitised and strengthened Soil Landscape mapping information
2) used GIS and digital elevation model technology to disaggregate and portray previously described but unmapped soil landscape facets
3) allocated capability constraint scores to each soil landscape facet
4) combined the resulting detailed soil landscape results with similar ratings for acid sulfate soil mapping and state of the art erosion hazard prediction surfaces and
5) produced final digital and hard copy maps for each land use, giving constraint scores for each 25 m pixel.

Land uses included standard, medium density, high density and rural residential development, cropping, grazing and on-site effluent management (for trench, irrigation and pump-out systems).

Study area and data sets used

The study area encompasses 3.8 million hectares stretching from the Queensland Border to the Hunter River and then continuing along the coastal escarpment from Shell Harbour towards Eden on the South Coast.

Soil landscapes and facets

Soil Landscapes are areas that can be characterised by repeating patterns of soils and landforms. Because similar causal factors are involved in the development of soils and landscapes, it is possible to use soil landscape mapping to naturally group the soil and landscape qualities which effect land capability. In NSW 1:100,000 scale Soil Landscape mapping includes the comprehensive assessment of numerous parameters which effect land use and land management. Facets are unmapped subdivisions of soil landscapes. In many instances soil properties can be readily predicted using terrain features. Using digital elevation models we were able to disaggregate, or separately present on a map many individual soil landscape facets. This process provides an extra level of detail that cannot usually be shown directly on 1:100 000 maps.

The soil and landscape constraint assessment process

The constraint assessment approach presented here is as outlined in Chapman and Gray (2005), Gray and Chapman (2005) and Yang et al. (2005). The approach is broadly based on the United Nations Food and Agriculture (FAO) framework. The rules for assessing capability for each land use type were based on extensive literature review and were assessed by an expert panel.

The assessment process involves evaluating the combined effects of a number of key soil and landscape attributes. Key principles behind the approach are based on the risk assessment framework within the Australian and New Zealand Standards AS/NZS 4360:1999:

Risk management—'the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood'

Residual risk management— 'the remaining level of risk after risk treatment measures have been taken'. For example, large residual risk levels remain on very steep sites with erodible soils in areas subject to intense summer thunderstorms. In such areas, standard soil conservation efforts often prove ineffective.

Quantitative costings—the effective costs associated with each class of constraint are estimated, facilitating the comparison of consequences of land use change. Further detail on the costing process is given in the following paragraphs.

Constraint classes

Five classes of constraint, as applying to individual attributes, were defined:

Class 1: Very low constraint; very low residual risk; low treatment costs; straightforward or no maintenance; associated with negligible financial, environmental or social site costs; acceptable to society.

Class 2: Low constraint; associated with minor financial, environmental or social site costs; straightforward or low maintenance; low residual risk; acceptable to society.

Class 3: Moderate constraint; moderate financial, environmental or social costs beyond the standard; frequent maintenance required; moderate residual risk; marginally acceptable to society—other factors may intervene. Each attribute falling into this class represents a cost equivalent to approximately 10% of a benchmark cost

Class 4: High constraint; high financial, environmental or social costs beyond the standard; special mitigating measures are required; regular specialist maintenance; moderate to high residual risks and costs; not usually acceptable to society. Each attribute falling into this class represents a cost equivalent to approximately 30% of a benchmark cost

Class 5: Very high constraint; risks very difficult to control even with site-specific investigation and design; very high financial, environmental or social costs beyond the standard; regular specialist maintenance may be mandatory; residual risk is high; not acceptable to society. Each attribute falling into this class represents a cost equivalent to approximately 60% of a benchmark cost.

Cost allocations

The definitions include quantitative proportions of benchmark costs (including financial, environmental and social costs) associated with each class. These benchmark costs vary for different land uses or qualities. For development uses (eg, standard residential or medium density development) the benchmark costs are the estimated initial construction costs (eg, $150 000 for constructing a standard house on an ideal site). Costs may also accumulate over the life of the development (nominally 100 years). For domestic wastewater disposal, the benchmark cost is the estimated cost of establishing a reliable surface irrigation disposal system, valued at approximately $10 000.

Each constraint class (1 to 5) was assigned a ‘constraint score’ representing the degree of associated financial, environmental and social costs. These scores apply to individual attributes or constraints, which are added to give a total score for a particular site. Each point of the score represents an approximate additional cost of 10% of the benchmark costs as shown by Table 1.
The constraint score allows a comparison of the costs associated with the land use change at different sites.

Table 3. Scoring and costing of constraint classes (scores apply to individual attributes).

	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint
Score	0	0	1	3	6
Additional cost to land use (%)	0	0	10	30	60

Results

Using the above approach we produced raster maps showing the relative cost of achieving sustainable development for twelve types of land use. Each map covers 3.8 million hectares of coastal NSW.
An example of a constraint map produced for the Coastal Comprehensive Assessment process is shown in Figure 1.

The maps are prepared on a 25 m x 25 m raster basis with constraint scores and associated data being allocated to each cell (see Figure 1). The constraint scores shown on all maps range between 0 and > 12, with a green to yellow to red colour ramping representing the increasingly high scores. Other supporting information associated with each pixel includes:
Constraint code - the ratings applied to all constraints/attributes considered in the assessment process.

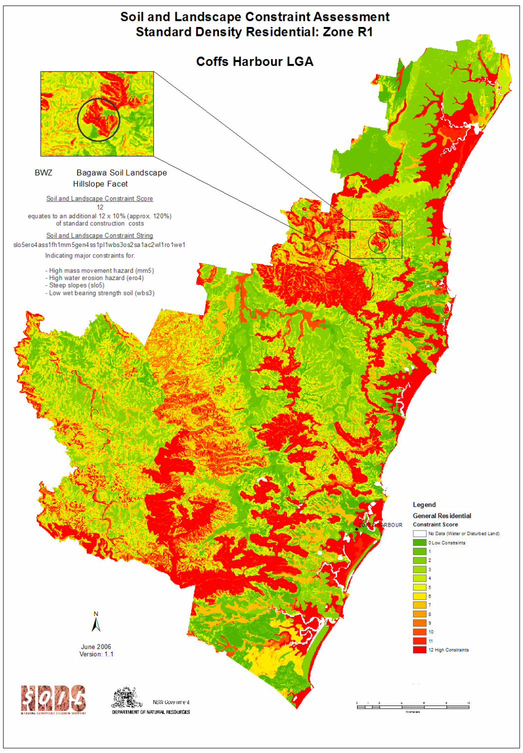

Figure 1. Soil and Landscape Constraint Assessment Map for Standard Residential Development (LEP Zone R1) for Coffs Harbour LGA.

Confidence rating – for each constraint score, ranked as: certain, confident, probable or uncertain, based on theoretical correlations and reliability of data
Unit identifier – the map number, soil landscape code and facet name to which each pixel belongs is provided. For example, 9541cuz_hillslope refers to the Murwillumbah-Tweed Heads 1:100 000 map sheet (9541), Cudgen soil landscape (cuz) and hillslope facet. Further description of the soil landscape unit may be obtained by referring to the relevant published soil landscape report.

Testing the outputs
A rigorous process of testing and review has been undertaken, including comparing results against existing capability ratings, field checking and review by soil surveyors familiar with different areas. This led to identification of minor errors and weaknesses and significant improvements in the process. The results now have a high degree of reliability, and are expected to be correct within one constraint point over 90% of the time.

Discussion and conclusions
The soil and landscape constraint assessment maps and supporting information present a clear indication of the nature and degree of soil and land constraints affecting various land-uses at different locations in the coastal area. They provide an indication of the consequences and effective economic costs of proceeding with different land use scenarios. The presentation of constraints in terms of estimated dollar costs, such as proportions of initial development costs, facilitates interpretation by land use planners and land managers. They will also be more meaningful to development proponents and the wider community.
The information is being used to:
Assist urban and regional planning processes including the preparation of planning instruments. Inform decisions relating to granting of consent to development applications and applying accompanying conditions. Identify appropriate specific use and intensity of land use Help determine project feasibility, appropriate design and likely environmental impact control measures at a particular site

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