First Approximation: Evidence-based Soil Health Investment Prioritisation for NSW

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Acronyms

ABS	Australian Bureau of Statistics
GSG	Great Soil Group
LLS	Local Land Services
LSC	Land-Soil Capability
MCAS-S	Multi-Criteria Analysis Shell
MER	Monitoring, Evaluation and Reporting
NRC	Natural Resources Commission
OEH	Office of Environment and Heritage
SESS	Soil Ecosystem Services
UNE	University of New England

Acknowledgements

Greg Chapman of Land and Soil Capability Consultancy for undertaking the map production through use of MCAS-S, and Tom Barrett of Office of Environment and Heritage, NSW for the Compendium of mapping rules and expert advice on use of MCAS-S.

Disclaimer
This is the first attempt or approximation at state level to set priorities for investment with the best available state-wide datasets. Whilst the technology and datasets are the best available, and they have been produced in good faith, there may be areas of NSW where perverse priority settings have prevailed due to data errors, unexpected programme errors or miscalculations.

1. Introduction

A key goal of the NSW Government is to protect and restore land across the state, including its soils to support the social, economic and environmental values of its communities (NSW Government 2012). Land degradation is currently impacting these values across many areas of the state. For example, data from most of the soil monitoring sites in NSW shows poor or very poor ratings for land management within land capability for at least one degradation hazard (EPA 2012).

The NSW Government has asked the Natural Resources Commission (NRC) to recommend a funding profile for Local Land Services delivered through its *Catchment Action NSW* funding program. The NRC intends to use the best available state-wide priority mapping to help develop its recommendations. However, there is currently no state-wide priority mapping for soils (and land management more broadly). Historical investment in these types of knowledge products has been traditionally low in NSW compared to other natural resource management issues such as vegetation and water (NRC 2012).

The NRC has asked the University of New England (UNE) to analyse, identify and map potential state-wide priorities for allocating investment to areas that are under greatest level of reaching irreversible damage to soil condition. The NRC has also asked the UNE to:

- consider systems and resilience thinking recently used by all NSW Catchment Management Authorities (CMA) to upgrade Catchment Action Plans
- use the best available state-wide and national data, for example soil condition and land management within capability monitoring data collected under the NSW natural resource monitoring, evaluation and reporting program and land management survey data collected by the Australian Bureau of Statistics (ABS)
- use the best available decision support tools such as the Australian Bureau of Agriculture and Resource Economics Multi-Criteria Analysis Shell (MCAS-S) (ABARE 2011)

This report presents the UNE's analyse and findings including:

- a raster map of state-wide soil condition investment priorities;
- a raster map showing the relative comprehensiveness and signal for confidence in using the data for decision making;
- an outline of the methodology and supporting materials;
- a list of assumptions, risks and limitations and prioritised future actions for improvement and potential future uses of the outputs; and
- recommended next steps.

A set of spatial working MCAS-S files has been delivered to the NRC.

2. Overview of methodology

The methodology to identify state-wide priorities in this report is based on the approach used by the Hawkesbury-Nepean CMA to identify spatial land priorities at a regional scale for their upgraded Catchment Action Plan. Appendix 1 presents this method in detail as a power point presentation, but is also described at length in (Chapman *et al., in press*) for the Hawkesbury-Nepean Catchment.

This report presents the first attempt to apply the methodology at a state-scale. The analysis for this report takes advantage of recently available data sets such as:

- individual soil condition and land management site scores from the 2008 and 2009 NSW Monitoring Evaluation and Reporting program (Chapman *et al* 2011, Gray *et al*, 2011).
- a preliminary analysis undertaken by the ABS's farm and land management practice data (2010) reported according to land capability spatial clusters (Chapman *et al* in press)[1].
- updated land use mapping for selective land cover types from the GeoScience Australia Dynamic Land Cover dataset http://www.ga.gov.au/earth-observation/landcover.html.

These data sets were not available in 2012 at the time of the assessment in the Hawkesbury Nepean CMA region

Key Methodological Steps

The key steps in the analysis include:

1. construct maps for soil condition and land management within land capability using MCAS-S data layers
2. summarise, combine and map (with MCAS-S) data for individual soil condition and land management scores according to soil type and land use
3. model and map areas where soil condition data is not available, unreliable or considered out of date which includes:
    a. constructing confidence limits for each indicator/land degradation hazard based on the relative usefulness of data for decision making maps.
    b. preparing maps by adding a score for the comprehensiveness of the dataset according to soil type and land use according to the number of available sites, to the score for strength of signal (mean/standard deviation).
4. individual confidence maps for each indicator were averaged into a single confidence map which was then normalised.
5. add available ABS land management practice versus areas available for sustainable implementation to supplement NSW land management within capability MER data.

[1] This work was commissioned by the NSW Office of Environment and Heritage

6. divide soil condition layers by land management within capability layers obtain tipping point data for each hazard..
7. combine mapping with soil ecosystem service maps for water quality, productivity, carbon and soil biodiversity reservation values.[2]
8. provide a map of priority areas, through MCAS-S, an average map of soil ecosystem service values was constructed and multiplied by the average tipping point value map.
9. display a final modelled output by reclassifying the normalised confidence map (of the data) against the priority investment map as shown in a two way table (Figure 1).

3. Spatial Priorities for investment

Figure 1 shows the modelled outputs from the analysis. It shows areas from high to low priority for investment (and future data gathering) across the state.

The final map was produced by multiplying the normalised confidence map against the priority map and a two way table used to show the following investment classes. There are three investment classes:

1. **Areas of highest priority for investment**.

Areas of highest priority for investment are shown in Red.

These areas have high levels of soil ecosystem service values and are rapidly approaching tipping point with a high level of certainty based on data confidence.

The total area of this category is **8.7 Million ha**, representing **10.8 per cent** (10.8 %) of NSW.

2. **Areas of highest priority for investigation**.

Areas of highest priority for investigation are shown in Yellow.

These areas have high levels of soil ecosystem service values and data suggests that they are rapidly approaching tipping point, however the certainty is low based on the data confidence.

The total area of this category is **4.8 Million ha**, representing **6 per cent** (6 %) of NSW.

These areas should have high priority for further data collection and investigation to reduce uncertainty. They also include areas with no data and therefore no confidence

3. **Areas where secondary action is required**.

Areas where secondary action is required are shown in Green.

[2] These were developed by OEH for the Hawkesbury Nepean CMA (Chapman et al., *in press*) (see attachment).

These areas have lower priority but relatively high certainty based on data confidence. These areas should be addressed after areas of highest priority have been ameliorated.

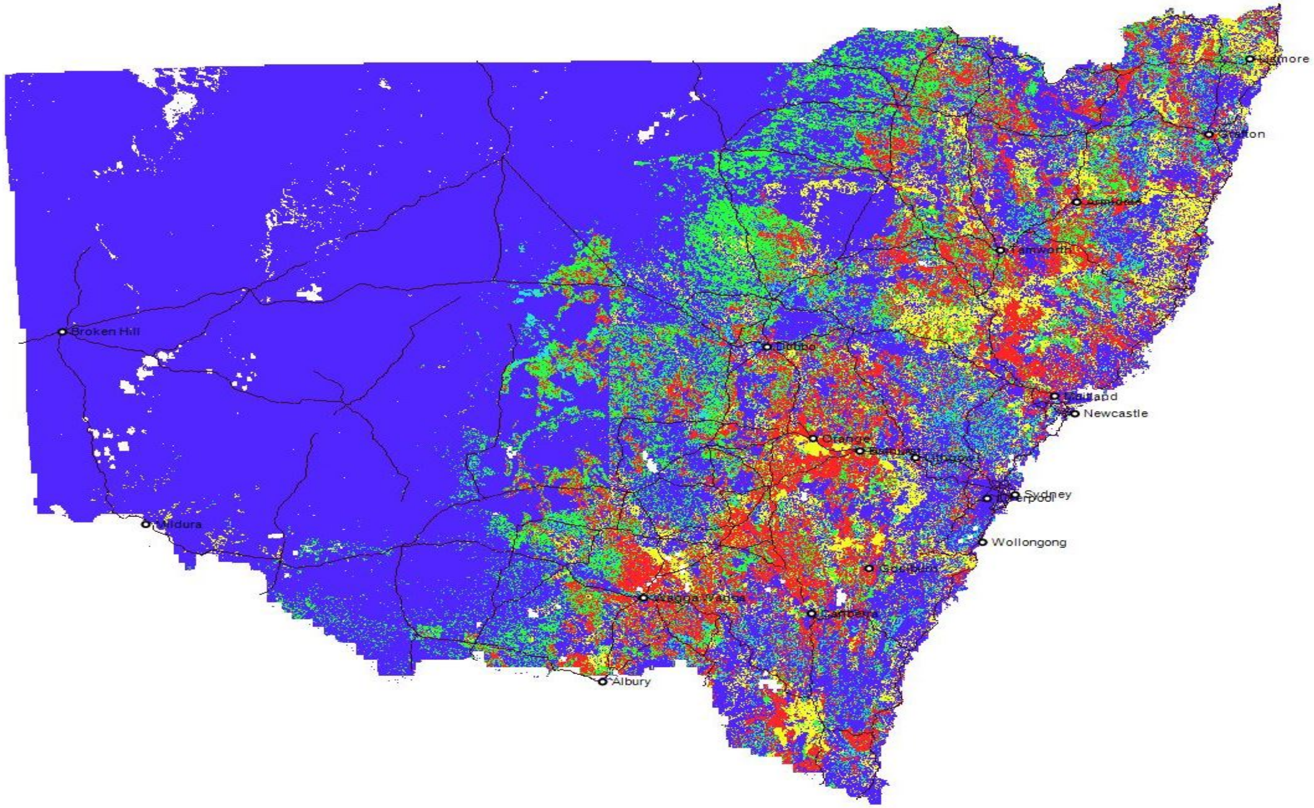
The total area of this category is **8.6 Million ha**, representing **10.7 per cent** (10.7 %) of NSW.

4. **Areas where low priority action is required**.

Areas with low priority areas for action are shown in Blue..

These areas have variable levels of soil ecosystem service values as well as the certainty of the data is also variable based on the data confidence.

The total area of this category is **58 Million ha**, representing **72 per cent** (72 %) of NSW.



Low Priority
Secondary Action Required
High Priority for Investigation
Priority Action for Investment

Figure 1: Priority areas for soil intervention in NSW

4. Assumptions, risks and limitations

In summary:

- A key limitation of the project is lack of confidence in the data over some areas of NSW, mostly due to soil types and land use combinations which have no or limited soil condition monitoring information.
- A program or series of modest programs to consolidate known data sets, and to target important high priority land use and soil type combinations are recommended such as a harmonised tenure layer.
- The prioritisation scenario presented is essentially static and assumes stability of land use and land management practices, and needs to be able to account for impacts of changes and shocks.

It is important to note that changes to input layers do not automatically generate updated MCAS-S project file results. The suggested tasks in Appendix 2 take into account modification of the various input layers. Once those layers are updated it is then recommended that the MCAS-S project can be rerun, rather than re-running after each data layer is upgraded.

This approach avoids duplication of effort as data in a single MCAS-S project file will not automatically be updated in dependant project files, even though it will propagate when an updated data file is included with the same file name. For instance, thirty four (34) project files have been used to generate the state priorities output.

5. Recommended next steps

UNE recommends the following key steps to address the current limitations and increase confidence in the modelled outputs. Appendix 2 also identifies priorities based on the greatest gain for least effort.

1. **Decision trail of mapping assumptions**

   Complete a more detailed documentation of MCAS-S models using compendium dialogue mapping tools that has been customised to reflect MCAS-S operations. This could be the basis for an expert review process.

2. **Improvements in spatial model of uncertainty**

   The confidence two-way tables are an example of this in action, but further improvements could be done using the scale of underlying state-wide composite data layers as a surrogate for spatial and attribute uncertainty.

3. **Sensitivity analysis and review of assumptions**

   Sensitivity analysis would examine the repercussions to modelled outputs if weightings and cut-offs were incorrect, as well as which input variables are the models most sensitive to or have the greater influence on the modelled outputs. Sensitivity analysis would help refine the prioritisation of data gap filling and refinement and improve the model confidence.

   Systematic review of assumptions relating to relationships and interactions between variables in the models, is currently being examined in point 1, but assumptions and sensitivity analysis could also be tested under point 4.

4. Expert review and refinement of the MCAS-S Model and its outputs

Building on from points 1 and 3 facilitated workshop/s with experts to review and refine model methodology and inputs, that is the interactions, assumptions, weightings, cut-offs, data sets and so on.

5. Scenario-building and reflection

It is recommended that consideration be given to running climate change and impacts on land use and land management scenarios. The prioritisation scenario presented in this report is essentially static and assumes stability of land use and land management practices.

Resilience analysis should include assessment of changes and shocks to the system. Global scale predictions for population, demographics, increasing affluence and food demand, coupled with expected supply peaks for oil and fertilisers and changes expected due to climate change have many implications (Cribb, 2010), including pressures on the maintenance of NSW soil condition.

Changes in soil condition may be dramatically affected by greater severity of drought, flooding and fire. Whilst the impact and timing of such trends is difficult to predict they can be expected to impact on the distribution of land use and land management practices, even in some cases impact on land and soil capability, which can be predicted. Such changes in soil condition can be expected to influence the soils' ability to deliver ecosystem services and social capacity for natural resource management.

In 2014 the NSW OEH will have access to NARCLIM, a set of climate predictions at 5 km grid scale, for NSW. It is recommended that prioritisation be repeated with updated climate data and expected variations in land use and land management resulting from food demands and higher fuel and fertiliser prices.

6. Workshops with users of modelled outputs and refinement based on local knowledge

Local training, evaluation and identification of uses with Local Land Service staff in MCAS-S interpretation, and scenario-building to define their needs and to operate at a Local Land Service scale. For instance the development of soil condition programmes for Local Land Services as a potential use for strategic planning.

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Appendices

Appendix 1: Explanatory Power point

Prioritisation of Soil Condition

For Local Land Services

Requirements

- Analyse and identify state-wide spatial priorities for allocating investment in soil condition to areas with greatest threat of reaching irreversible decline (tipping points)
  - Using spatial resilience thinking
  - Using best available statewide data
  - Using MCAS-S
- Report with maps and maps of confidence in the data
- Report on the methodology

Process and principles

- Land capability is resilience and resilience is lost when soil condition is lost
- Focus on threats which are most immediate – ie condition/sustainability of management practices is smallest = priority
- Confidence is about the extent and signal provided by data. High confidence and high priority = onground action. Low confidence and high priority = investigation. Priority is ranked

Deliverables – Files with

- MCAS-S data set with sub projects and numerous maps for NSW
- This power point presentation
- Main background documents and
- Main background power point presentations

Main documents

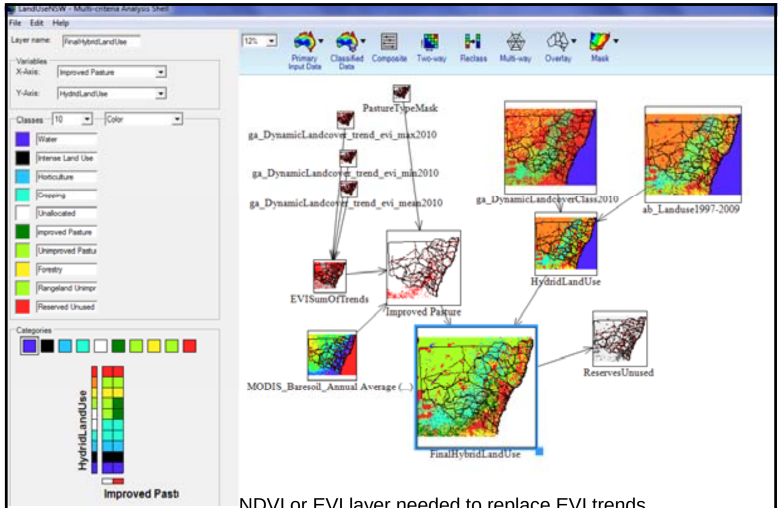
- *Spatial resilience prioritisation for regional soil condition improvement using available data in NSW datasets.* Draft Jan 13 Chapman et al Draft & accompanying powerpoints
- *Land management practices and land capability in NSW: Interim analysis of ABS data* Chapman and Gray May 2013 Draft
- This powerpoint.

Process Overview

- Hybrid land use map constructed and tested. Individual land use masks produced numerically to match NSW Soil and Land Land Use categories
- Assemble NSW Soil Condition maps by land use and soil type from pivot tables from the NSW Soil and Land MER database
- Assemble assumed NSW Soil Condition maps from modelled data for salinity, wind and sheet erosion
- Assemble NSW Land Management within capability maps (LMwC) by land use and soil type from MER database.
- Assemble confidence maps (site count score added to signal ie mean/SD) for each available soil condition and LMwC hazard. Compile into a single confidence map.
- Incorporate available ABS land management practice exedence maps with LMwC
- Compile tipping point maps from soil condition and LMwC and combine into a single priority map
- Review and modify Soil Ecosystem Service maps for NSW
- Relate tipping points to soil ecosystem services and confidence. Report on proportions of Local Land Services within categories for action priorities and investigation priorities
- Report and comment on methodologies strengths, weaknesses and cost future improvements

Land Use map updating

- NSW AB land use is old 1997, and does not match MER land use categories eg improved pasture is missing.
- Geoscience Australia Dynamic Land Cover misses many categories but is up to date, especially for pasture and cropping. Does not include improved pasture.
- Combined both data sets using 2 way look up table and discriminate voluntary/native and improved pastures using enhanced vegetation index and bare soil responses (PTO)

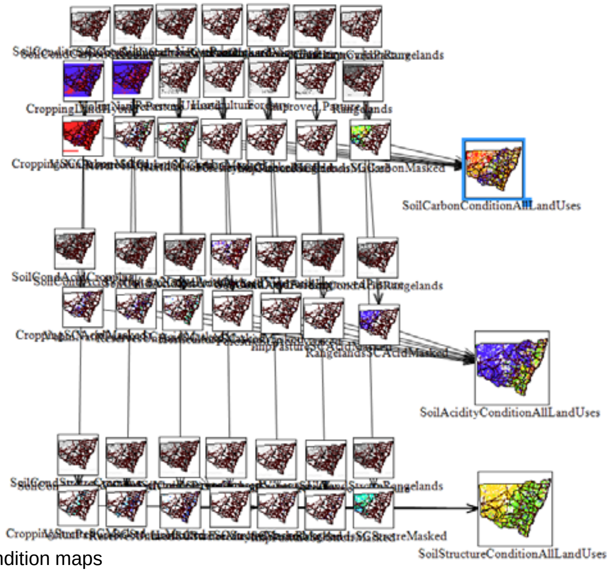


NDVI or EVI layer needed to replace EVI trends

Soil Condition Mapping Steps

- Pivot tables produced for each indicator (carbon, structure and acidity) using site score means by soil type and land use combinations.
- Means entered to MCAS-S soil type map: 1 map per landuse (7) and per indicator (3) = (21) maps
- Land use maps mask for land use
- Add masked maps together and repeat for each indicator. PTO for example.

Adding mean soil condition values by great soil group for cropping - unmasked

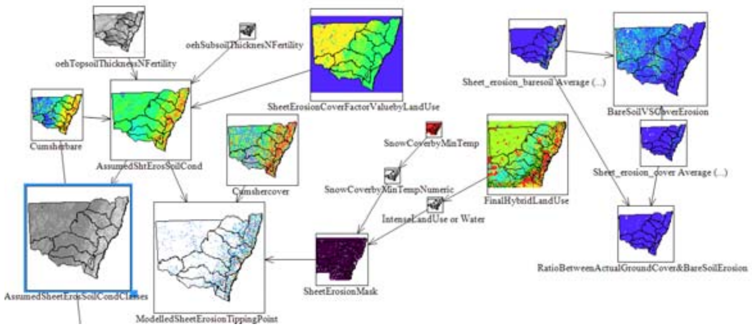


Making Soil Condition maps

Sheet Erosion Condition Mapping

- No maps or data exist for sheet erosion condition, wind erosion condition or salinity condition.
- Interim maps were made by modelling factors which influence these indicators and by substituting space for time for mean ground cover by land use. The maps are assumptive but mostly match expectations. Require more consideration and work.

Sheet erosion condition and modelled tipping point mapping: PTO for explanation



Sheet Erosion Condition modelling

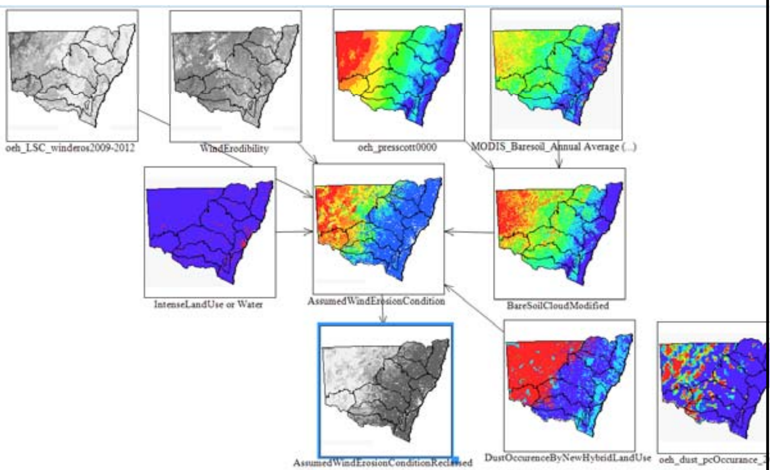
- Sheet erosion condition relates to remaining functional soil depth (reference depths and fertility of topsoil allocated and mapped by great soil group
- RUSLE and mean cover factor for land use reported and mapped using MCAS-S and arbitrarily weighted by 100 (based on ratios between bare soil and cumulative ground cover sheet erosion) to influence post-european soil condition changes (assumes static cover and static land use over last 10 years)
- Outputs reclassed to MER 1-5 values by deciles

Assumed Wind Erosion Condition Modelling

- Bare soil time series filled where cloud effected, exclusion of water and intense land uses
- Soil type values allocated and mapped for wind erodibility
- Dust occurrence time series reported and mapped as means for land use and values
- All multiplied together and reclassed

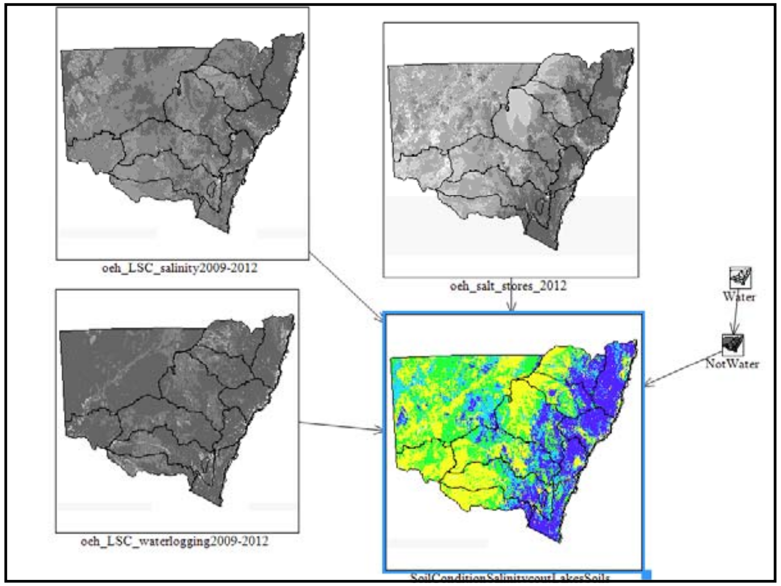
PTO

Wind erosion condition modelling.



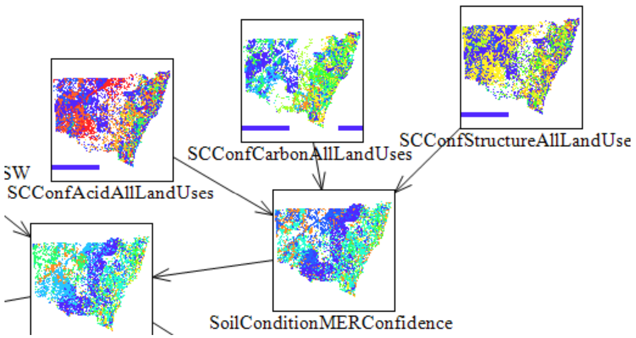
Assumed Soil Salinity Condition Mapping

- Assumed salinity condition is based on salt stores, water logging (for discharge) and land and soil capability of salinity for areas which lack salinity.
- Work is required to add layers which show how natural salinity has altered (eg report by mean ground cover impact on evapotranspiration)
- Confidence is low but mostly matches expectations
- Salinity outbreak layer reported by GSG and Land Use then remapped?



Combining Soil Condition maps

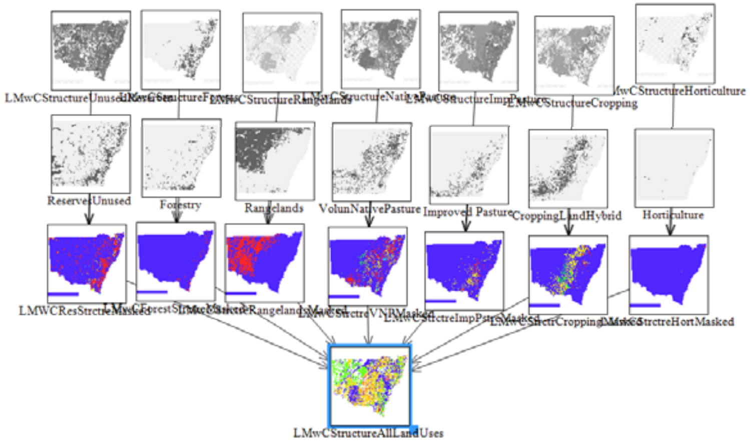
- Maps for each soil condition indicator where normalised 1-5



Land Management within Capability Mapping

- Pivot tables produced for each of 6 hazards (sheet erosion, wind erosion, salinity, carbon, structure and acidity) using site score means by soil type and land use combinations.
- Note: LMwC does not distinguish gully erosion and no gully erosion maps yet available for MCAS-S
- Means for soil type and land use combination entered to MCAS-S soil type map: 1 map per landuse (7) and per hazard (6)
- Land use maps mask for land use
- Add masked maps together and repeat for each hazard.
- PTO for example

Land Management within Capability mapping example – soil structure



Confidence Mapping

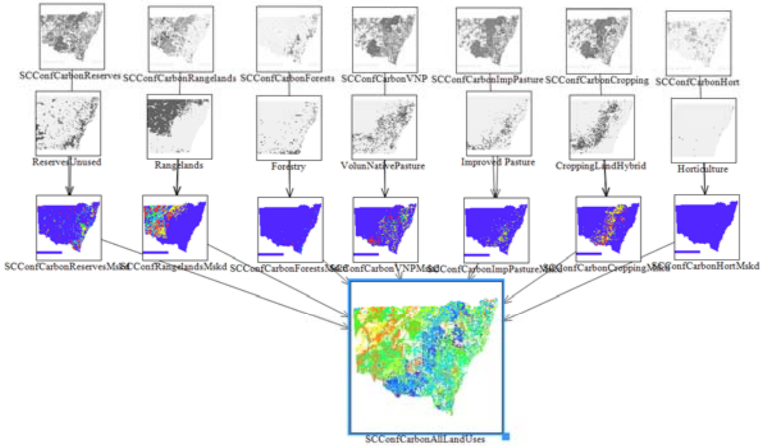
- Confidence is based on the extent (ie score for the count of sites) and signal to noise (ie mean/SD) [Stokes 2008] of LMwC for soil type and land use combinations

Signal to noise rating by integer up to 5 [Stokes, 2008]

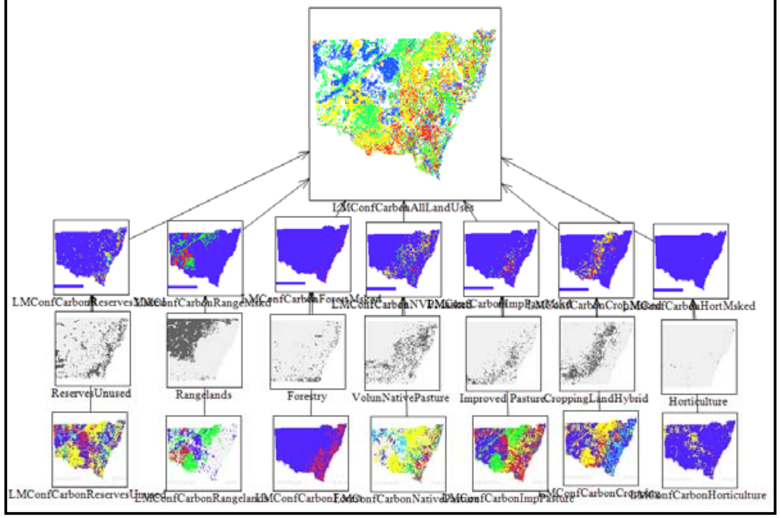
Site Count: <1, <4, <8, <12 <16, >16

Extent Score: 0, 1, 2, 3, 4, 5

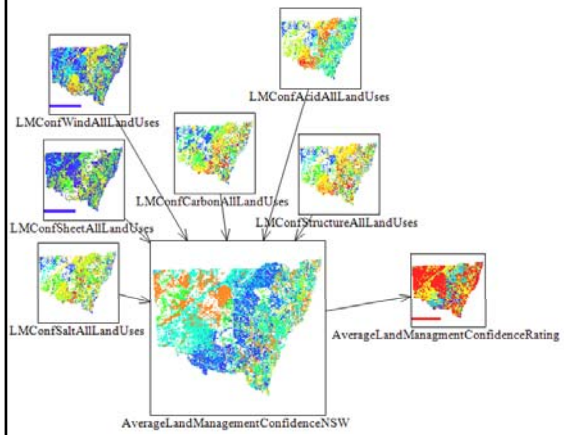
Soil condition confidence – mapping by soil type, mask by land use and then combine for each of six hazards – carbon example shown



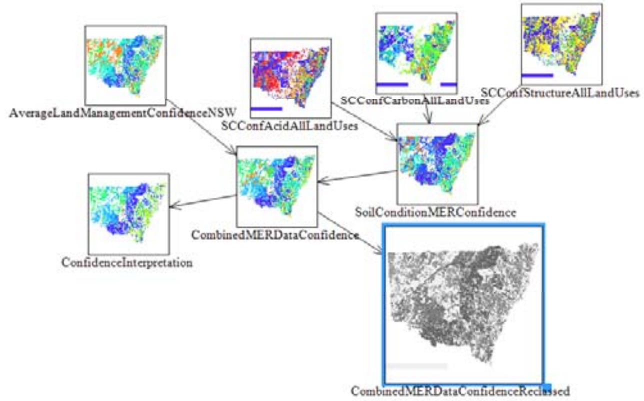
Land management for soil carbon within Capability confidence. Confidence scores mapped by soil type masked for land use and then added together



Combining land management confidence mapping into a single map



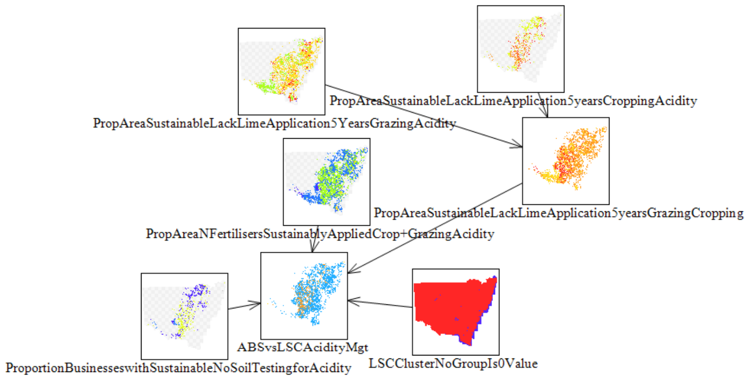
Averaging and combining land management within capability and soil condition confidence scores. Reclassed 0-1



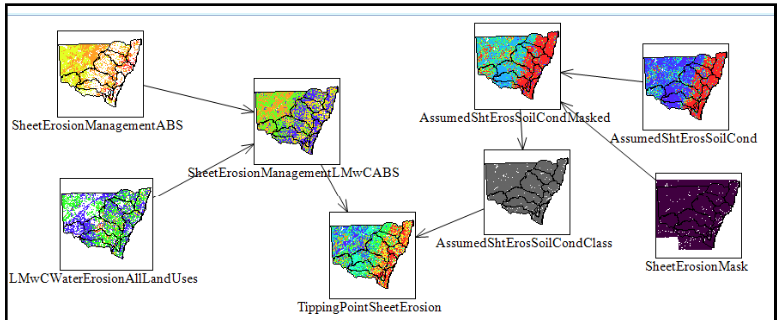
Adding ABS layers

- ABS vs LSC is available for some - but not all- land management practices for acidity, soil structure and water erosion. Others need to be redone or produced from scratch
- ABS vs LSC calculations are on a sustainable area exceeded whilst Land Management within Capability is a matter of degree for limited sites
- Work is required to make all ABS layers spatially available, to incorporate with all six hazards, and to assess comprehensiveness and consistency with LMwC practices.

ABS vs LSC layers for soil acidity



Combined by normalising both to 1-5 MER range and averaging

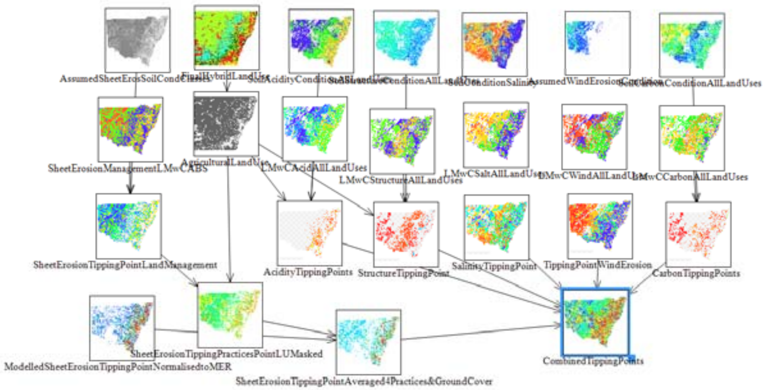


Data ranges for ABS vs LSC and LMwC are both normalised with no ratings when input to sheet erosion management

Tipping Points

- Tipping point is the relative immediacy of reaching an irreversible lack of soil function. It has been calculated for each indicator as Soil condition divided by Land Management within capability.
- Small values indicate greatest immediacy of reaching tipping point

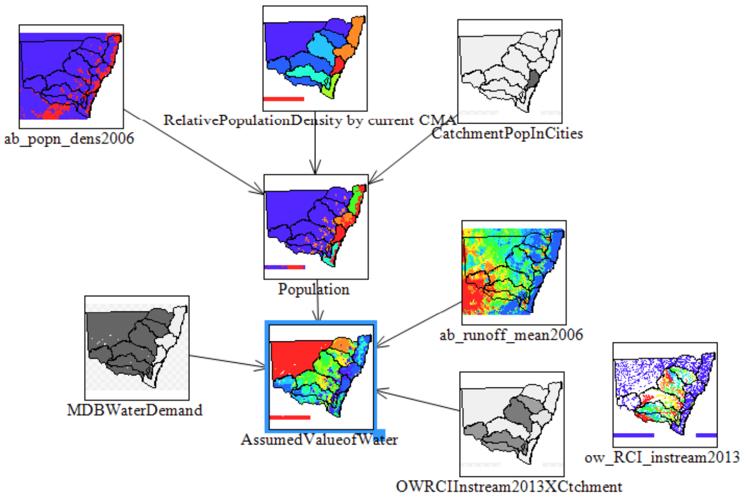
Summary combined tipping points map

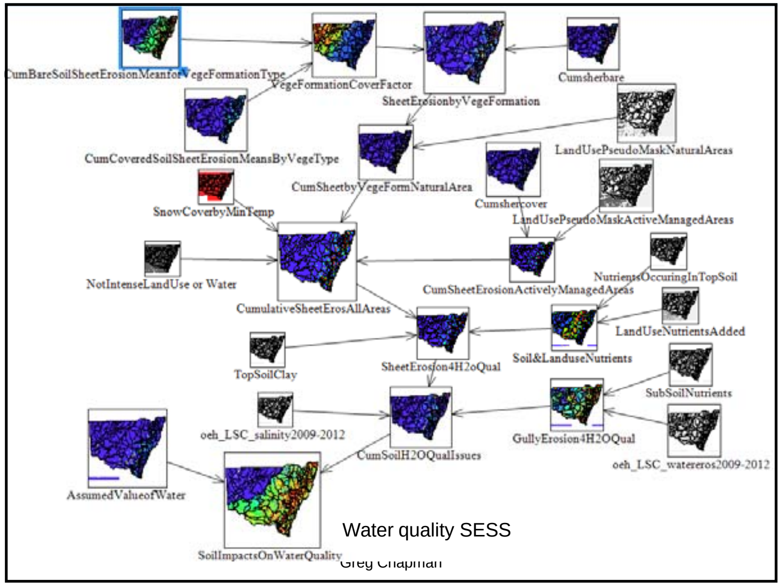


Soil Ecosystem Services SESS

- Soil Ecosystem Services are the values delivered by soils for human and ecological benefit.
- Land with greater ecosystem service value should have higher prioritisation if approaching tipping point
- Soil Ecosystem Services were determined for Water Quality benefit, Productivity, Soil Carbon increase and Soil Biodiversity as per Chapman *et al* for the Hawkesbury Nepean CMA.
- The water quality SESS is judged against the human value of surface water. This layer requires more work by water experts

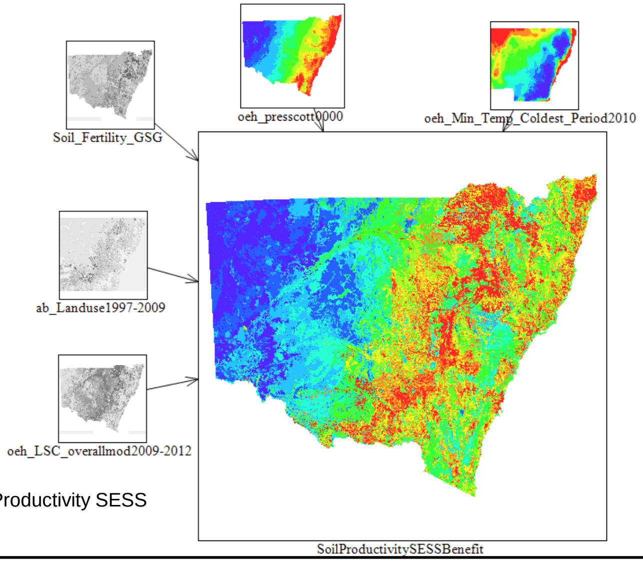
Assumed water values mapping for use in Water Quality SESS





Water quality SESS

Greg Chapman



Productivity SESS

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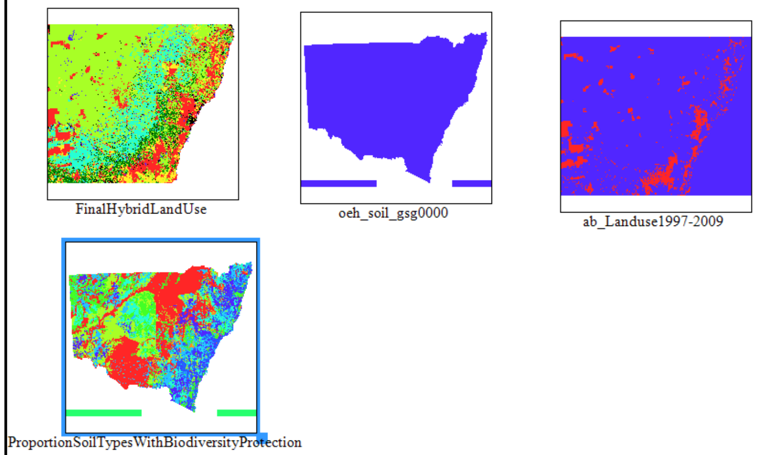
Soil Biodiversity SES – soil types with the least amount of conservation



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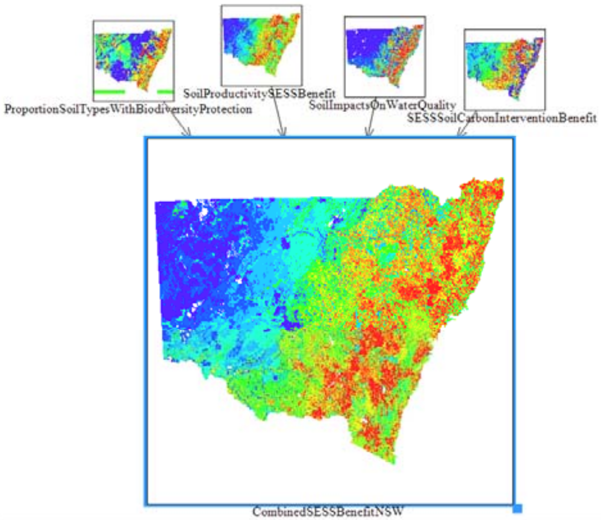
Combined Soil Ecosystem Services by addition



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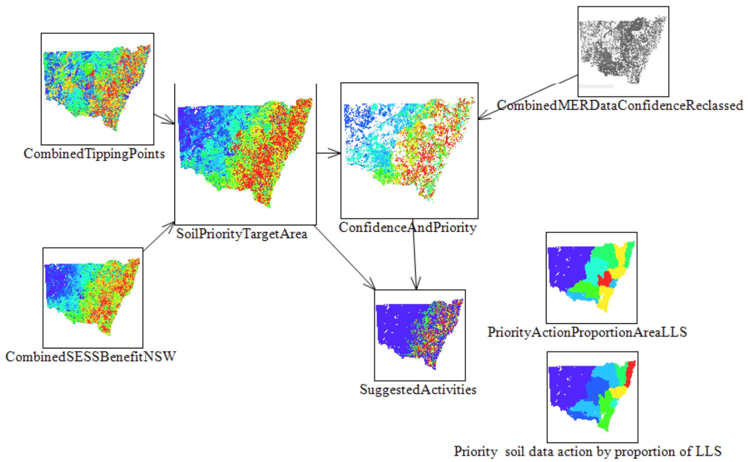
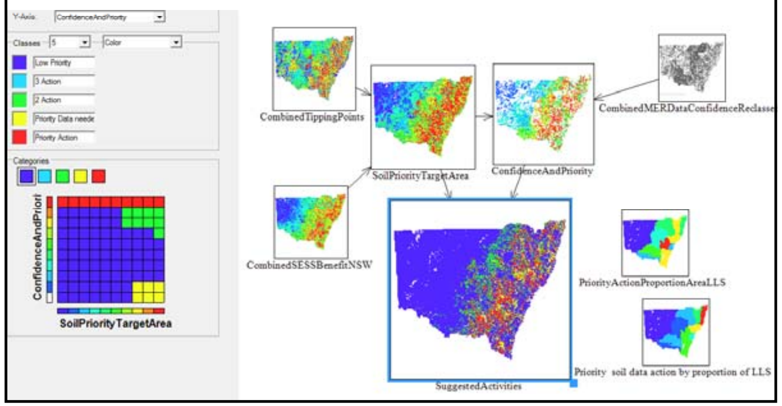
Combining tipping points, SESS and confidence combination



Putting it all together: Suggest activities are priority area values in a two way table VS confidence and priority. Actions divided between high confidence and priority, Low confidence and priority and high investigation priority as well as secondary priority

Next screen is the relative proportion of these by Local Land Service Area



Priority areas by LLS

Local Land Service	Low Priority Action	Secondary Action	Priority Data needed	Priority Action
Central Tablelands	0.395804017	0.117316426	0.150273442	0.336606115
Hunter	0.451548531	0.108892074	0.194724464	0.244834932
Northern Tablelands	0.471824578	0.170494303	0.113887145	0.243793974
South East	0.512352558	0.109477849	0.138579078	0.239590515
Riverina	0.587405803	0.163632056	0.065069266	0.183892875
North Coast	0.479877833	0.100449666	0.258058537	0.161613964
North West	0.570074262	0.217134706	0.070221194	0.142569839
Central West	0.57150714	0.266100633	0.039360599	0.123031628
Greater Sydney	0.714413569	0.102224357	0.085699941	0.097662134
Murray	0.763364999	0.131218782	0.03516303	0.07025319
Western	0.989072744	0.00776434	0.001656414	0.001506502

Figures are the proportion of the LLS

Proportion of local land service area with highest priority tipping points

Data in priority Data needed indicates high priority or no information but poor data confidence

Land and Soil Capability for UNE
Greg Chapman

Last slide

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Appendix 2: Summary of data assumptions, risks and limitations

Issue		Comment	Order of priority[3]
		Land use mapping	
1.	**Improved pasture mapping**	Improved pasture is a new land use category which requires update. It was put together using Enhanced Vegetation Index trends and requires a mean Enhanced Vegetation Index time series on the assumption that improved pasture has higher level of greenness for longer than voluntary or native pasture - due to species mix for production and inputs such as fertiliser. Solution: OEH to provide NDVI or EVI time series averages for NSW.	**2**
2.	**Lack of a mixed farming layer**	MER results and land uses are based primarily on a snap shot of the land use prevailing at the time of sampling or on the most commonly prevailing land use during sampling. Map of mixed farming to be assembled from Dynamic Land Cover layers and data extracted from MER land use history on a site by site basis.	**11**
3.	**No composite tenure mapping layer for land use**	This layer is likely to be often used, but is not available as a harmonised layer. There are separate layers for different tenures under State Government Departments such as forestry, national parks and lease-hold land. Relatively easy to rectify but would require some checking to ensure the layers are aligned. There is an option to ask DPI and Lands in NSW to provide best available tenure layers to OEH to convert to MCAS-S format.	**12**
4.	**Land use history**	Assumptions for development of modelled soil condition layers is that land use and land use practices are essentially static - there is only one land use layer. However, it is well known for instance that record stock levels in the 1890s caused massive land degradation in the western division (Russell and Isbell 1986).	
5.	**Timber scrub unused**	This particular land use is a poorly defined. Such land may have already degraded or has been episodically used well beyond its capability. If the land was truly unused then it would be expected that scores in this land use category would be close to reference condition. To resolve this inconsistency a desktop examination of each site in this category by Google Earth and conduct field examination. If this category of land use is universally poor then further work may be required to build a case for better management of unused often publically owned land. This may have large ramifications for Local Land Services.	**14**
6.	**Hardwood and softwood plantations**	This land use has not been discriminated. Soil conditions and management actions could be expected to be very different but there is a lack of evidence. Solution: DPI Forestry could be asked to supply this mapping as part of the tenure mapping exercise. The MER project had very few soil condition sites in forested areas.	

[3] Most gain with least effort

Issue		Comment	Order of priority[3]
Soil type mapping			
7.	**Great Soil Group (GSG) Categories**	The GSG do not completely match with the soil types as the GSG are mapped at a 1: 100 000 or 1:250 000 scale. The mapping of the GSGs is based on dominant GSGs from soil landscape mapping. It does not show for more localised soil types which are often described in reports, It is possible to digitally discriminate the less dominant soil types for many parts of NSW and this would greatly enhance the quality of the outputs. Secondly, great soil groups derived for the SALIS data card (Milford et al, 2001) used in the MER process are different to the Great Soil Groups used to discriminate soil impacts on land capabilities and shown on the NSW Land and Soil Capability map. Examples of inconsistencies either in lumping or splitting GSGs are below: LSC does not distinguish between brown, grey or red clays whereas MER soil condition data does. LSC GSG has two groups for alluvial soils MER has one. LSC GSG has two groups for yellow podzolic and two groups for red podzolic soils and two groups for red earths whilst MER has one of each. Solution: 1) wait for current OEH mapping in NW NSW to be completed and re-examine riverina mapping to discriminate clay groups. 2) desktop examination MER sites where discrepancies occur with a view to reallocation.	**6, 13**
8.	**Discrimination of great soil groups with distinct geographic entities**	Some GSG represent several distinct soil types and this tends to blur the results. Of these GSGs many have disjunct distributions, allowing each soil type to be separately mapped. For example siliceous sands are confined to sand dunes in western NSW, source bordering dunes in the central division and to coastal dunes. Each of these should be separately mapped, for example using MCAS-S eg proximity from the coast and rainfall/aridity features because each type has completely different conditions and land management.	**6, 13**
9.	**Great Soil Group Lookup Tables**	Values assigned to great soil groups, except for erodibility have been based on expert opinion. To validate the values assigned to each GSG than expert verification or workshopping could be conducted.	**6, 13**
Soil condition			
10.	**Lack of data for some soil types and land use combinations eg Forestry and Horticulture.**	Solution: this could be rectified by Local Land Services making a modest investment soil information where it is lacking. This may be by site sampling, eg using SoilWatch, or if sufficient quality data already exists by entering it to the NSW Soil Condition and Land Management database. Existing data sets are known for the Lachlan, Murray, Northern Rivers and Central West Catchments.	
11.	**MER soil group allocation errors and unallocated soil types and land uses**	Approximately 5 percent of MER sites are labelled with no suitable group or are unlabelled for these key fields. Solution: Desktop investigation of soil maps and Google Earth may provide likely data.	
12.	**Land Management Practice History**	Assumptions for development of modelled soil condition layers are that land management practices have remained essentially static which for certain practices are not the case. An example is the adoption of conservation tillage techniques from the 1980s to being relatively widespread by 2010.	

Issue		Comment	Order of priority[3]
13.	**Site scores for soil condition indicators and land and soil capability mapping are based on relatively simple but accepted rules.**	The rules are outlined in Bowman *et al*, (2009). Improvements through more sophisticated process modelling would be expected to increase confidence in allocation of site scores. Solution: OEH soil scientists could use digital soil modelling to assess soil condition values for pH and soil carbon, wind erosion and sheet erosion. Whilst the models exist a carefully designed program would be required over the medium term.	
14.	**Gully erosion soil condition.**	Soil condition for gully erosion for the 2008 MER baseline was based on clusters of gully erosion sites (Chapman *et al.*, 2011). Scores for individual gullies and their great soil groups and land uses are not currently readily available. Because of the collection sampling method they cannot be confidently extrapolated as gully erosion soil condition across NSW and further investigation would be required to determine if the data would be useful for state-wide prioritisation. However, a map of density of gullies has been previously produced using data from air photo mapping of individual systems. This map may be useful for assessing gully erosion condition.	
15.	**Acid Sulfate Soil Condition and Land Management within Capability.**	Acid sulfate soil risk map constituent layers are required to assess acid sulphate soil tipping point. Processing to tipping point involves rule mapping Land and Soil Capability to acid sulphate soils and mapping soil condition by land use and soil type/land form element.	
16.	**Evapo-transpiration factor for Salinity**	An evaporation transpiration look up table is required to assess land use impacts on salinity. This table should be readily available from OEH.	
17.	**Impact of wind erosion**	Soil deposition by wind erosion has not been taken into account. Requires discussion with wind erosion experts and adding a look up table to be developed by the MCAS-S project.	**5**
18.	**Insufficient Information on Small-Scale Land Uses**	Land uses such as vegetable production, hobby farming, and urban areas have no soil condition data. These areas are currently masked. Anecdotal evidence suggests some land uses such as vegetable production are losing soil condition, but additions such as fertiliser are masking the loss of soil condition.	
		Land and soil capability	
19.	**Land and Soil Capability by dominant Soil Landscape Facet**	Soil landscapes often contain repeating patterns of more than one soil type. The LSC and Great Soil Group maps are based on LSC for the soil type of the largest or most dominant facet. This may not be representative of most of the landscape. A programme to map soil landscape facets may be of benefit to Local Land Services.	**16**

Issue		Comment	Order of priority[3]
20.	**Land Management within Capability bias**	The NSW MER programme (Chapman *et al.*, 2011, Gray *et al.*, 2011) may have unrepresentative sites and site bias, which is part of the point raised earlier about **Timber Scrub unused**. It is also suspected that in some situations the reported situation is better than reality. The same is suspected for the ABS data with a positive bias. It may be possible to assess differences in various aspects of the data sets eg by correlating satellite based ground cover monitoring against survey results.	
21.	**ABS Land and Land Soil Capability**	Assumptions and problems with the use of ABS survey data are reported in Chapman *et al* (in press).	**15**
22.	**Areas in NSW with unallocated LSC clusters**	There are some LSC map polygons which were not assigned LSC clusters (see Chapman *et al*, in press), presumably because of missing or corrupt data.	**7, 9**
23.	**Unmapped and corrupt ABS LSC management practice layers.**	There are numerous land management practices which have not been analysed.	
		Soil Ecosystem Services	
24.	**SESS Water value mapping**	The use and value of water is an important layer which could be vastly improved by: • incorporating an MCAS-S layer showing the catchments of public dams fed primarily by runoff in NSW • provision of a table which indicates the area of irrigation, human population dependant on the drinking water and number of stock (dse) dependant on the dam water. • Weighting for the importance of the MDB water leaving NSW. This has arbitrarily been assigned a weighting of 2 compared to eastern flowing water to the coast which were assigned a weighting of 1.	**8**
25.	**SESS Carbon calibration.**	Whilst the relative spatial pattern for SESS Carbon looks reasonable, it has not been calibrated against actual soil carbon levels into the future. The simple model for soil carbon SESS should be assessed by experts with a view towards rescaling to fit more detailed modelling. This may be achieved by comparing the SESS Carbon Maps with MCAS-S Digital Soil Modelling layers produced by OEH.	**4**
26.	**Productivity calibration**	Similarly productivity SESS should be calibrated against existing data such as Net Primary Productivity or mean NDVI or mean long term EVI.	**3**
27.	**Guidance on relative weightings for the SESS**	Is water quality more important than productivity or soil biodiversity or soil carbon? No weightings have been placed on any of these soil ecosystem services? Should they be? Advice is required.	

Issue		Comment	Order of priority[3]
Tipping points			
28.	**Synthesis between LSC and SESS**	Decisions/assumptions on weightings and interactions between forms of land degradation are difficult as they are not simply linear relationships, and some may have negative or positive feedback loops. More direct cause and effect relationships are shown when erosion of a neutral topsoil leaves behind a more acid subsoil or loss of soil structural condition in the topsoil leads to increased rates of soil erosion. Others are more complex such as increased leaching in induced acidity leading to greater discharge rates hence causing salinity and waterlogging elsewhere in system or increased use of direct drilling improving soil structure and causing increased recharge and rising water tables. None of these interactions have been attempted or weighted	
Presentation and outputs			
29.	**Overlay**	Local Land Services in overlay is required. This will help with interpretation and deliverables. This is a simple case of obtaining the shape file from OEH in MCAS-S format.	**1**