xstrata coal

04 October 2011

The Research Director
Environment, Agriculture, Resources and Energy Committee
Parliament House
George Street
BRISBANE QLD 4000

VIA EMAIL TO: earec@parliament.qld.gov.au

Dear Mr Hansen,

Thank you for the opportunity to provide this submission to the Environment, Agriculture, Resources and Energy Committee (the Committee) on the **Strategic Cropping Land Bill 2011** (the Bill). This submission is made on behalf of Xstrata Coal Queensland (XCQ).

Overview

The Bill creates much uncertainty for resource development in Queensland generally, and for planned investment by XCQ specifically, because:

- The Bill does not include an explicit definition of 'strategic cropping land';
- The science underpinning the Bill is fundamentally flawed according to two independent scientific reviews (reproduced here as Attachment 1 and Attachment 2); and,
- Exemptions afforded the resources industry for 'well advanced' projects are extremely short-lived and repeated triggering of the SCL legislation [i.e. via S22(1)(b)] adds significant uncertainty to future resource investment.

Xstrata Coal Queensland Pty Ltd (ABN 69 098 156 702)
Level 10 Riverside Centre 123 Eagle Street Brisbane Queensland Australia 4000
GPO Box 2587 Brisbane Queensland Australia 4001
Tel +61 7 3115 5300 Fax +61 7 3115 5412 www.xstrata.com

Specific comments on the SCL Bill

Section	Effect	Comment	Recommendation
S2	Commencement on earlier of accent date or 30 January 2012	This is a very short timeline for the Committee to make proper and considered recommendations to the Parliament. This Bill is a complex and important piece of legislation, with potentially significant ramifications for both resource development and farming in Queensland.	Commencement on 30 June 2013 to allow (i) proper and considered review of submissions (ii) the science underpinning the legislation to be reviewed and enhanced, ensuring it is robust and correct (iii) formulation of meaningful recommendations to the Parliament
S4	Definition of SCL remains vague.	Throughout Policy development, SCL has been described variously and inconsistently by Government. The draft State Planning Policy for SCL contained no definition at all. The definition in the Bill is vague and circular.	Provide a clear and unambiguous definition of SCL. For example, 'SCL is the best cropping land' is a definition that has been widely used by stakeholders during Policy development.
S8	Dictionary "in Schedule 2 defines particular words..."	The dictionary in Schedule 2 does not contain a definition of SCL, but does contain a circular reference to S9.	Provide a clear and unambiguous definition of SCL.
S9	Ambiguously and rather circularly defines SCL as "land recorded...as being SCL."	The Bill does not contain a clear, unambiguous definition of the land to which it applies.	Provide a clear and unambiguous definition of SCL.

Section	Effect	Comment	Recommendation
S10	Potential SCL is land shown on the trigger map.	The trigger map is grossly inaccurate. DERM themselves have cautioned that due to the broad scale of the spatial datasets used in the creation of the trigger maps, they are not recommended for use below a scale of 1:250,000 and should not be used at a property scale. All SCL assessments will be conducted at a property scale. The effectiveness of the trigger maps in identifying the possible presence of SCL, and reliably initiating on-ground assessment at a property scale, is highly questionable. See report by Palaris (2011), reproduced here as Attachment 1.	The trigger maps serve no reliable purpose in the identification of SCL and should be deleted from the Bill.
S11(4)(b)	If impacts are temporary, "fully restore the SCL to its pre-development condition."	What is "pre-development condition"? Is this different to achieving "SCL status"?	Either: (i) Define "pre-development condition" and the process for proving it; or, (ii) Change the wording to 'achieving SCL status' or words to that effect.

Section	Effect	Comment	Recommendation
S11(5)(a)(ii)	"...mitigation measures must have a value at least equal to the loss of the lands productive capacity as cropping land."	It would be extremely difficult to determine a dollar amount for the "lands productive capacity as cropping land" given the uncertainties of (i) seasonal climate fluctuations; (ii) climate change; (iii) different farming systems; (iv) past, present and future farming practices; (v) macro-economic assumptions; (vi) etc. This would require some form of complex exercise in agro-economics with multiple input assumptions on rainfall, climate, commodity pricing, etc.	Set a fixed fee for mitigation ($/ha) that does not require the uncertainty and vagaries of complex agro-economic modelling. This will limit any re-interpretation or mis-interpretation of payment requirements.
S14(1)(c)(i)	The definition of permanent impact includes the activity of "open-cut mining".	To exclude a land use, e.g. open-cut mining, without regard to potential or actual impacts (i) is contradictory to the Precautionary Principle; (ii) is inconsistent with current approaches to impact assessment under the Environmental Protection Act 1994; (iii) is, at best, based on anecdotal evidence of current open-cut mine rehabilitation practices and outcomes; (iv) is a disincentive to improve current rehabilitation practices and outcomes.	Delete this section.

Section	Effect	Comment	Recommendation
S22(1)(b)	An application, which triggers the SCL Act, is also 'an amendment, a renewal and a re-grant'.	This is greatly concerning as any amendment to an Environmental Authority for a resource tenure, which occurs frequently, would allow repeated application of the SCL Act. Potential ramifications include retrospective conditioning, never-ending assessment, and lack of certainty for Authority holders.	SCL assessment should occur once, at the time of original application only and this should not be subject to repeated triggering.
S28	Protection areas	The 'protection areas' were decreed (i) without any quantitative assessment of the subject land; (ii) without scientific justification; (iii) without agro-economic justification; (iv) without stakeholder consultation; (v) without consideration of the Standard Criteria for Ecologically Sustainable Development as prescribed in the EP Act 1994; (vi) without due consideration to the potential and real social, environmental and economic impacts.	Delete this section.
S40(2)(c)(i)	An application is prohibited if a "cropping history decision has already been made..."	This circumvents the on-ground assessment process to determine is the land meets the SCL criteria and thresholds. It is commonly accepted that much cultivated land in Queensland, as elsewhere, is marginal with respect to sustainability of cropping production.	Delete this section.

Section	Effect	Comment	Recommendation
S45, S46	Applications relate to "properties" consisting of lots owned or managed by common parties	The distribution of soil types and resource tenure do not recognise real property title boundaries. These sections would require a resource proponent with a tenure application across multiple real property titles to make multiple applications.	Delete these sections.
S48(a)(ii)	Zonal criteria compliance	The zonal criteria and threshold limits are based on flawed science. (i) "The proposed criteria and thresholds are not effective and will not reliably discriminate the best cropping land from other land. The threshold limits are generally too low. This has two broad consequences; viz. (i) their usefulness is restricted to merely identifying land that is not suitable for viable farming, as opposed to distilling the "best" cropping land from all other, and (ii) any viable cropping land is generally identified as SCL." Palaris (2011), reproduced here as Attachment 1. (ii) The Australian Society of Soil Science Inc. (ASSSI) provided a submission to DERM on 21 July 2011 (reproduced here as Attachment 2), in which they stated they were "dismayed at the creation of yet new criteria to identify the most productive cropping land;" and highlighted "critical errors of fact" in relation to the criteria.	Remove the criteria from the Act (Part 2), and place in subordinate Regulation or similar. Given the grave concerns expressed by Palaris and ASSSI (Attachment 1 and Attachment 2) it is likely that the criteria and threshold values will need significant amendment post-implementation. This will more easily be achieved if the criteria and threshold values are listed in Regulation or guidelines.

Section	Effect	Comment	Recommendation
		It appears that the recommendations of Palaris and ASSSI were not adopted by DERM.	
S49	Cropping history test/s	The test for cropping history is extremely weak, to the extent that it will prove largely irrelevant. A total of 3 crops or, worse yet, 3 cultivations, in a 12 year period would hardly indicate the land is of value for food production security.	Substantially re-write this section to require a cropping frequency of at least 6 crops in 12 years. Delete reference to cultivation only, as this would only serve to reward poor farming practice.
S60	Zonal criteria requirements	Please refer to comments for S48 above	Please refer to recommendations for S48
S62	Minimum land area requirements	It is unclear to what land these minimum land area requirements will apply, i.e. will they apply to the real property lot area, the criteria compliant SCL area or other land? The Policy intent has always been that the minimum land area requirements apply to areas demonstrated to be SCL only.	Amend the wording of this section as follows. "The ***minimum size***, for SCL, is the following size for the following zones—..."
S127(2)(d)	"the classification, grade or quality of the relevant resource" is disregarded in consideration of alternative sites for exceptional circumstances provisions	This is very concerning. Just as all soils are not the same (some will be SCL and some will not), so all coals are not the same either. No resource development for coal could ever pass the exceptional circumstances test as currently presented.	Delete this sub-section.
S132	Mitigation value?	Omitting the "mitigation value" from the Act adds further uncertainty to the future viability of resource development in Queensland.	Prescribe the "mitigation value", i.e. a dollar value per hectare, in the Act.

About Xstrata Coal

Xstrata Coal is a major coal mining company that develops, owns and manages several coal mining operations in Queensland, including mines at Collinsville, Oaky Creek, Newlands and Rolleston.

Xstrata Coal in Queensland produces 29.5 million tonnes of coal per annum for export and domestic use. We employ more than 3,100 people in Queensland, paying wages of over $199 million each year. Our operations also support many other indirect jobs in Queensland.

Xstrata Coal contributes to the growth of regional communities in Queensland, as well as making significant contributions to Queensland's export revenues, royalties and direct and indirect employment for Queenslanders.

In 2010 Xstrata Coal's total expenditure in Queensland on goods and services, royalties and labor exceeded $2.2 billion.

- Royalties $329 million
- Port and Rail $424 million
- Labour $199 million
- Community Investment $5 million
- Goods and Services $1,202 million

Since 2005, Xstrata Coal has invested $1 billion in Queensland in new mines and expansions.

Xstrata Coal has a pipeline of major projects in Queensland that, if approved, will see us invest $12 billion in Queensland. These projects include the Wandoan Coal Project, Sarum Coal Project, Rolleston Coal Expansion, Balaclava Island Coal Export Terminal and other mine expansions.

Xstrata Coal is the proponent of the Wandoan Coal Project, a proposed 22 million tonne per annum coal mine near the township of Wandoan. Construction of this mine will commence in 2012.

Xstrata Coal is the proponent of the Balaclava Island Coal Export Terminal, a proposed 35 million-tonne-per-annum capacity terminal south of Rockhampton. The draft Terms of Reference for the Environmental Impact Statement for Balaclava Island Coal Export Terminal project have been finalised by the Coordinator General.

Xstrata Coal is also involved in joint industry projects that, if approved, will see a further $7 billion invested in Queensland port and rail infrastructure. These projects include Wiggins Island Coal Export Terminal and Rail, Surat Basin Rail, QR rail upgrades and the Wandoan Power Project with Carbon Capture and Storage.

Summary

Xstrata Coal is a major investor, employer and economic contributor to Queensland.

It is our overwhelming opinion that the SCL Bill

- Is based on flawed science that does not withstand rational, objective scientific scrutiny according to two independent scientific reviews (reproduced here as Attachment 1 and Attachment 2)
- Requires significant amendment prior to assent
- Is complex and important for all Queenslanders, and the Committee should be given more time for sober review, stakeholder consultation and formulation of considered recommendations for the Parliament

Thank you again for the opportunity to provide this submission to the Committee.

We trust that our constructive comments and opinions, and the facts and recommendations highlighted herein, will be considered by the Committee and assist to frame recommendations it makes to the Parliament.

Yours faithfully,

Reinhold Schmidt
Chief Operating Officer
Xstrata Coal Queensland

[attached]

Attachment 1

Manuscript date: 10 June 2011

A review of the proposed methodology for identification of strategic cropping land in Queensland

Evan C. Thomas[A], *Andrew L. Bauer*[A] *and Terrence A. Short*[AB]

[A]Palaris Mining Pty Ltd, Brisbane, Qld 4001

[B]Corresponding Author. Email: tshort@palaris.com.au

Abstract. Identification of Queensland's best cropping lands, and their protection from inappropriate development has been identified by the Queensland Government as an important component of land use planning for sustainable development. This paper reviews the methodology (trigger maps, zone maps and criteria with thresholds) proposed for identification of strategic cropping land (SCL) in Queensland and an accompanying technical report detailing development and testing of the methodology. The review concentrates on the Western Cropping Area zone (the Western zone) which covers about one third of the state and includes renowned farming districts, i.e. Darling Downs and Central Highlands, and resource development areas, i.e. Bowen, Surat, West Moreton and Galilee basins. An application of quantitative land evaluation methods, including APSIM, is used to test and quantify thresholds for the key cropping limitations. Government's proposed methodology is based on mapping and a small set of eight soil-related criteria with threshold values. No explicit definition of SCL is provided and, rather circularly, the criteria which describe SCL are also said to define it. The process used to develop and test the criteria and thresholds is semi-empirical and subjective, relying on the experience of the assessment team, and risks bias. This paper demonstrates that the methodology is unlikely to reliably discriminate SCL from other land, because: (i) current trigger maps are not appropriate for use at a property-scale; (ii) zone maps do not adequately account for variations in climate, soils and farming systems; (iii) several of the criteria are ineffective discriminators; and, (iv) the proposed criterion threshold values are generally too low. The principal limitations to viable cropping in the vast Western zone are rainfall variability and the capacity of soils to store moisture. It is shown that this zone should be split into seven smaller regions, each with different thresholds for soil water storage capacity and minimum land area requirements. Quantitative evaluation suggests minimum soil water storage thresholds for Eastern Downs, Western Downs, Roma and Central Highlands regions are 100 mm, 120 mm, 175 mm and 135 mm, respectively. This review demonstrates that Government's proposed methodology for SCL identification is deficient, and would benefit from inclusion of modern, quantitative approaches to land evaluation and an explicit definition of SCL. The methodology as proposed, risks incorrect land identification leading to either the sterilisation of marginal land from appropriate development or, most importantly, the risk of alienation of SCL by inappropriate development.

Introduction

The protection of cropping land from inappropriate forms of development is an increasingly common policy objective for governments (e.g. USA's prime farmland and Queensland's good quality agricultural land policies). Inappropriate forms of development are competing land uses which permanently alienate land from agricultural production.

Queensland is the first Australian government to mandate a new level of protection for cropping land. This land, termed *strategic cropping land* (SCL), is described as "*a scarce and natural resource identified by soil, climatic and landscape features that make it highly suitable for crop production*" (DERM 2010a). The Queensland Government states that SCL must be conserved and managed for the longer term (DIP 2010) and protected from development by competing land-uses, e.g. mining and urban development (DERM 2010a).

Ensuring a robust methodology for the identification of SCL, one which reliably discriminates between the best cropping land and all other land, is a vitally important component of land use planning for sustainable development. It will ensure that the best cropping land is preserved for agricultural production while still allowing the economic and development potential of other land to be realised.

This paper reviews the technical methodology developed for identification of SCL in Queensland. It highlights key factors that should be considered if similar methodologies are to be developed elsewhere.

The Queensland approach

The Queensland Government is developing a State Planning Policy and has released a Regulatory Assessment Statement, proposed criteria and a methodology for identifying SCL on-ground (DERM 2011b). This is supported by a technical assessment (DERM 2011c) which describes the process used to develop and test the criteria.

The general approach for identifying SCL is: *(1) The site meets the designated suitability scheme standards, which will require suitability for a range of crops; (2) The land is within the SCL climatic zone; and, (3) The land use does not preclude cropping* (DERM 2010a).

The proposed methodology includes the application of "trigger maps" (Figure 1) to quickly identify potential SCL; "zones" (Figure 2) that establish specific criteria for on-ground assessment; and sets of eight soil-related criteria for each zone to discriminate SCL from other land (Table 1) (DERM 2011b).

DERM (2010a) states that *"trigger maps"* are the starting point for determination of SCL, and once an area is 'triggered' as possibly being SCL, then it will be subject to on-ground assessment.

The eight soil-related criteria for on-ground assessment operate together in a diagnostic framework, with each applied sequentially to discriminate SCL from other land. If a criterion is not met, the area is deemed not to be SCL and further assessment is not required. The land resource must meet all criteria to be considered SCL (DERM 2011b).

The criteria are ordered from the simplest to the most complex, with a view to discriminating non-strategic cropping land as early as possible in the field to reduce time and cost. Criteria 1 to 5 can be assessed directly in the field, whereas criteria 6 to 8 may require some laboratory analysis.

Table 1. Criteria and thresholds for identification of SCL
(Source: DERM 2011b)

Criteria	Thresholds				
	Western Cropping	Eastern Downs	Coastal Qld.	Wet Tropics	Granite Belt
1 Slope	≤3%	≤5%			
2 Rockiness	≤20% for rocks >60 mm diameter				
3 Gilgai microrelief	<50% of land surface being gilgai microrelief of >500 mm in depth				
4 Soil depth	≥600 mm				
5 Soil wetness	Has favourable drainage				Has satisfactory drainage
6 Soil pH	For non-rigid soils, the soil at 300 mm and 600 mm soil depth must be greater than pH 5.0 For rigid soils, the soil at 300 mm and 600 mm soil depth must be within the range of pH 5.1 to pH 8.9				
7 Salinity	Chloride content <800 mg/kg within 600 mm of the soil surface		$EC_{1:5}$ <0.56 dS/m within 600mm of the soil surface		
8 Soil water storage	≥100 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm		≥75 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm	≥50 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm	≥25 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm

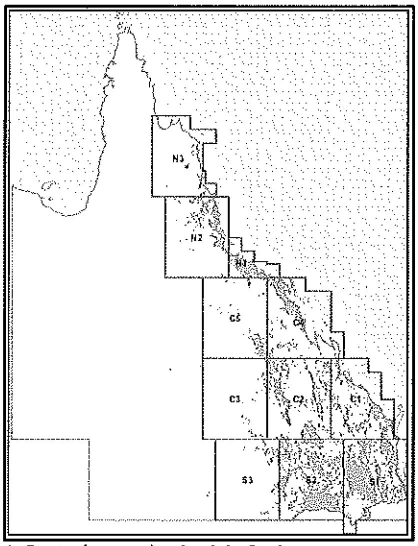

Fig. 1. Strategic cropping land draft trigger map composite. (Source: DERM 2010b)

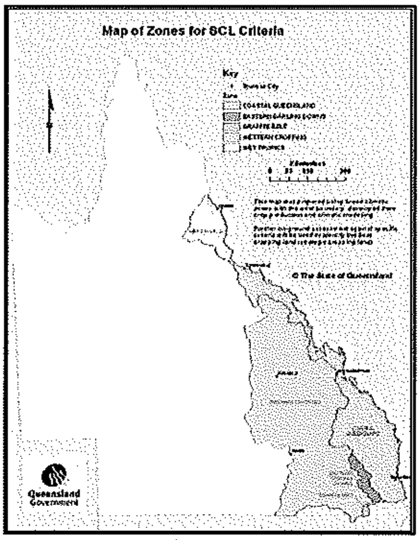

Fig. 2. Strategic cropping land zones. (Source: DERM 2011b)

Review of the Queensland approach

Definition of SCL

The Queensland Government has described SCL variably in a range of publications as the policy developed, viz. (i) *"...land areas with the best soil, climate, water supply (rainfall and/or irrigation) and infrastructure that supports cropping well into the future"* (Hinchcliffe, February 2010); (ii) *"...land that is suitable and available for current and potential future cropping with limitations to production that range from moderate to none"* (DIP, February 2010); (iii) *"...land on which soil quality, topography and seasonal rainfall combined enable more than one quality crop to be grown on a commercial agricultural basis"* (Robertson, August 2010); (iv) *"...a scarce natural resource identified by soil, climatic and landscape features that make it highly suitable for crop production"* (DERM, August 2010b); and, (v) *"...land that is suitable for a range of crops in most seasons"* (Jones, April 2011, Shaw 2011).

Later the Technical Assessment Report (DERM 2011c) presented a set of guiding policy principles that provide a high-level definition of SCL, i.e. soils that: (i) *are suitable for a range of crops*; (ii) *are capable of reliably producing crops*; (iii) *are capable of being cropped without excessive inputs, such as moderate use of fertilised, standard cropping machinery and limited soil conservation measures;* and (iv) *do not generally require irrigation for sustainable cropping*. DERM (2011c) adds that *"such land will be capable of being productively and sustainably cropped into the future based on their inherent attributes and management systems; and will be resilient to changes such as climate change and changes in the agricultural sector"*.

It is interesting to note that DERM (2011c) indicates the criteria developed to identify SCL, also define it. This contrasts with (i) biological classification, where criteria may help describe an entity, e.g. a species, but they do not define it; and (ii) Mackenzie *et al.* (2008) discussion on implementing land resource assessments (p438-444).

Trigger maps

About 2.2% of Queensland's land area is currently cropped (DERM 2010b; ACLUMP 2009). The amount of good quality cropping land or Class A land is even smaller, approximately 1.5% of the state and about a third of this is irrigated (DIP 2010; DERM 2010b). In contrast, all mining activities to date in Queensland have occurred on about 0.1% of land (QRC 2010; ACLUMP 2009).

The maps are to be the starting point in determining whether an area of land is SCL (DERM 2010b). The purpose of the trigger maps (Figure 1), 12 maps in total, is to indicate areas where SCL is expected to exist (DERM 2010a and 2010b).

These maps were reported to be based on the best soil, land and climate information currently available (DERM (2010a) and were *"prepared using land suitability data and a climate constraint of 500 millimetres average annual rainfall"* (DERM 2010b, p. 3). This climate constraint was later revised, apparently, to the 70th percentile, 450mm isohyet.

The 'metadata' for the SCL trigger map (DERM 2010e) confirms the basis of the maps as land suitability data but adds, that where this was insufficient, land use data was used, with various exclusions. Consequently, there is a high degree of correlation between the trigger maps (Figure 1) and Queensland land use mapping (Figure 3).

Data for Queensland's land use, by area, is provided (Table 2). This data shows 2.2% of the state is used for cropping (underlined in table) and this is consistent with DERM (2010c).

Closer examination of the trigger maps in the vicinity of Emerald (Figure 4) and other districts shows that the maps are based largely on recent landuse (1999 and 2004) and earlier soil mapping data. This soil mapping data dates from the 1960's and 1970's, and was produced at broad reconnaissance scales (1:250,000 or smaller, less

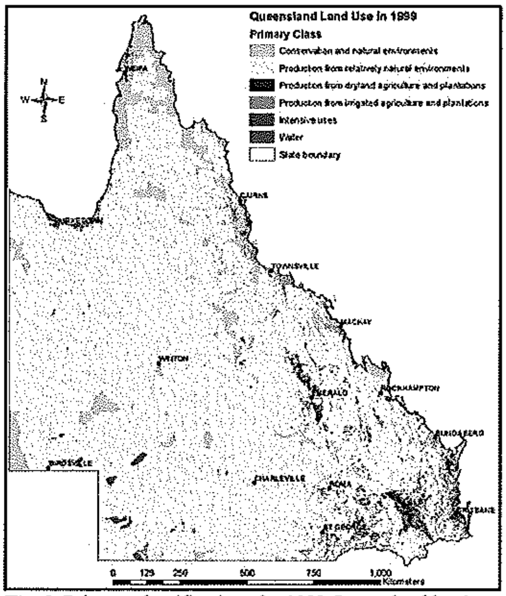

Fig. 3. Primary classifications for 1999 Queensland land use (DERM 2008).

Consequently, DERM (2010e) caution that due to the broad scale of the spatial datasets used in the creation of the trigger maps, they are not recommended for use below a scale of 1:250,000 and should not be used at a property scale. For explanation, the minimum observation or sampling density for land resource mapping at the 1:250,000-scale is a single sample per 6.25 square kilometres or 625 hectares (McKenzie *et al.* 2008). More than 80% of all cereal grain cropping properties in Queensland are much smaller than 625 hectares (Table 3). So too are mining leases. The mean size of all mining leases granted in Queensland in year 2010 was 182 ha (range <0.5 to 3533.6 hectares) (DEEDI 2011).

Table 2. Queensland land use by area
Information from ACLUMP (2009)

Land use	Area (km^2)	Area (%)
Nature conservation	79,501	4.6
Other protected areas	18088	1.0
Minimal use	36,767	2.1
Grazing native pasture	1,486,497	86.0
Production forestry	32,088	1.9
Plantation forestry	2,093	0.1
Grazing modified pastures	1,841	0.1
Dryland cropping	27,284	1.6
Dryland horticulture	208	0.0
Irrigated pasture	2	0.0
Irrigated cropping	9,820	0.6
Irrigated horticulture	1,019	0.1
Land in transition	127	0.0
Intensive animal and plant prod.	2,544	0.1
Intensive uses (mainly urban)	3,798	0.2
Rural residential	3,086	0.2
Mining and waste	1,206	0.1
Water	23,342	1.3
TOTAL	1,729,312	100

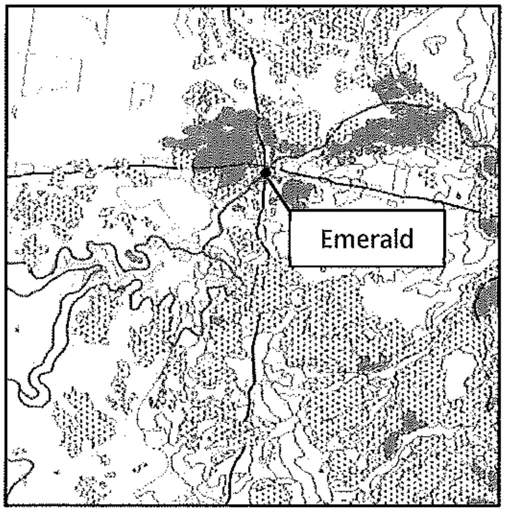

Fig. 4. Detail of trigger map in the vicinity of Emerald. (Brown colour is dryland cropping land use and green colour is irrigated cropping land use (DERM 2008), purple lines denote mapped soil units, grey dots indicate SCL trigger map layer (DERM 2010a)

Table 3. Mean property sizes – broadacre cereals for grain
Information from ABS (2008a)

Region	Number	Size (ha)
Eastern Downs	962 (48%)	193
Western Downs	760 (36%)	461
Roma	148 (07%)	738
Central Highlands	233 (11%)	791

Despite this concern, and the caution provided by DERM (2010e) that the trigger maps should not be used at a property scale, DERM (2010b) states that an SCL decision will be linked to resource tenure assessment processes. As the size of mining tenure represents only small properties, the effectiveness of the trigger maps in identifying the possible presence of SCL, and reliably initiating on-ground assessment of discrete mining tenures, is questionable.

In contrast to the scale of the trigger maps, soil mapping for mining environmental impact assessment purposes is required to be conducted at a scale of 1:5,000 for larger mines (DME 1995). This equates to a sampling intensity of more than four per hectare to provide the recommended density (DME 1995). As such, land suitability mapping currently required for mining environmental impact assessment is more than three orders of magnitude (~2,500 times) more detailed than the trigger maps.

Zones

A total of five discrete zones are identified, viz. Western Cropping Area, Eastern Downs, Coastal Queensland, Wet Tropics and Granite Belt (Figure 2) (DERM 2011b). The Western zone is the largest of the proposed zones, covering close to half a million square kilometres of land or about 28% of the state.

The purpose of the various zones is to accommodate different climates, soils, cropping systems and crop types (DERM 2010d). While this may generally be the stated desire of DERM, examination of the zone map boundaries (Figure 5) indicates their basis to be, more strongly related to, Natural Resource Management (NRM) areas, themselves based on major river catchment boundaries (DERM 2006). Notable exceptions include the Eastern Downs zone, demarcated by DERM (2011c) following identification of *"long term and highly productive cropping"* on slopes up to 5%, and the western boundary *"developed from crop production and climatic modelling"* by DERM (2011b). However, no report showing the quantitative assessment was provided to support either amendment.

The assumption that these areas would be largely homogeneous, in terms of climates, soils, cropping systems and crop types, may be true of the smaller zones. However, this may not be true for the very large Western zone.

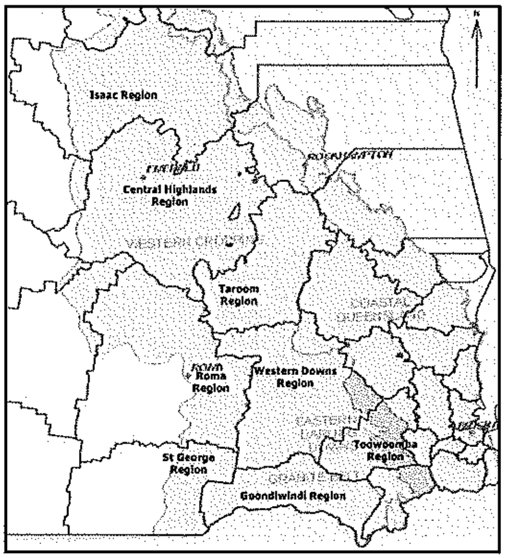

Fig. 5. Detail of zone map showing Western zone (light blue) and encompassed regions (DERM 2011b).

The Western zone extends from the NSW border approximately 1,000 kilometres to the north, and is, on average, about 500 kilometres in width. It includes the regions (i.e. local government areas) of Toowoomba, Western Downs, Roma and Central Highlands spanning sub-tropical and tropical areas.

DERM (2011c, p. 39) considered splitting the Western zone into smaller parts but state that *"no clear boundaries"* and *"no clear evidence or consensus could be obtained on what thresholds for which criteria could or should be different."* In contrast, clear evidence does exist to show that climate, rainfall, soils and land use vary significantly across this large area (e.g. Biggs 2007). Climate variability dominates cropping production in subtropical regions (Littleboy *et al.* 1990) like the Western zone and effects on yield have been studied extensively (e.g. Freebairn *et al.* 1990; Potgieter *et al.* 2002). Climate variability, although a synthesis of all-weather measurements over time, is often reduced to rainfall only in the study of cropping systems (e.g. Biggs 2007).

Examination of rainfall, crop yields and land use along transects within the Western zone highlights the considerable variability within this vast area. A west-to-east transect from Mitchell to Toowoomba demonstrates (i) the strong, and significant, trends in decreased rainfall variability, from moderate to low-moderate, and increased median annual rainfall, from 541 mm to 708 mm (Figure 6), (ii) the increased cropping productivity, from <2 t ha^{-1} to >4 t ha^{-1} of sorghum (Figure 7), and (iii) the higher proportion of cropping land use, from 3% to >20% (Figure 8). Similar trends have been discussed by others (e.g. Biggs 2007) and cropping in the Roma region is well documented as being rainfall limited (e.g. Freebairn *et al.* 1990).

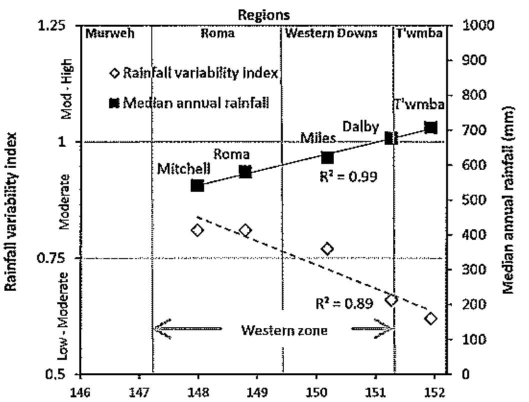

Fig. 6. Rainfall variability index (RVI) (P≤0.001) and median annual rainfall (P≤0.05) on a west-to-east transect from Mitchell to Toowoomba (BOM 2011).

Whilst there are similarities between areas within the Western zone, the land management manuals for the Maranoa (MacNish 1987) and the Darling Downs (Vandersee 1975; Marshall *et al.* 1988) further illustrate the wide variety of soil types and land use suitabilities in two key districts along this west-to-east transect.

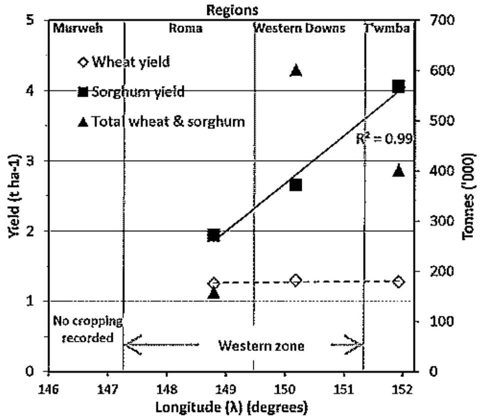

Fig. 7. Mean yields and total tonnes of wheat and sorghum (P≤0.1) (2000 – 2008) on a west-to-east transect from Mitchell to Toowoomba (ABS 2011a).

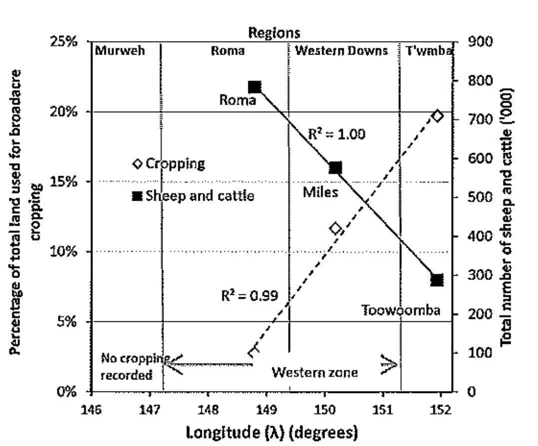

Fig. 8. Cropping area (P≤0.001) and total livestock numbers (P≤0.1) on a west-to-east transect from Mitchell to Toowoomba (ABS 2008a).

Criteria and thresholds

The proposed methodology specifies different thresholds for each of eight key soil-related criteria (see Table 1) that apply within each zone. The approach is to apply these sequentially, from the simplest field measurement, i.e. slope, to the more complex laboratory analysis, i.e. soil water storage, in a diagnostic process to discriminate SCL (DERM 2011a, 2011b).

This section largely concentrates on the Western zone as it is the largest zone, covering about 28% of the state including renowned cropping districts, i.e. Darling Downs and Central Highlands, and resource development areas, i.e. Bowen, Surat, West Moreton and Galilee basins. Within the Western zone, wheat and sorghum crops are by far the most extensively sown (ABS, 2008c) and therefore, this study focuses on these crop types. Notwithstanding, it is likely that the general conclusions will be broadly applicable to all zones.

Development and testing of the criteria and thresholds. Criteria and thresholds for identification of SCL have been proposed in DERM (2011b), tested and refined in DERM (2011c) and reviewed in Shaw (2011). DERM (2011b) is largely a summary of outcomes of DERM (2011c).

The approaches used to develop, test, and review the criteria are, at best, semi-empirical, because none is underpinned by quantitative assessment. These approaches are consistent with qualitative approaches to land evaluation, which rely on practitioner's experience, subjective understanding and interpretation of available research and data (McKenzie *et al.* 2008). The theme of the latest *Australian Land Resource Survey Handbook* by McKenzie *et al.* (2008) is the preference for application of more quantitative and objective approaches.

McKenzie *et al.* (2008) discuss approaches to land resource assessment and rank these according to the degree to which they rely on scientific principles, viz. (i) trial and error; (ii) empirical, relying on transfer by analogy; (iii) semi-empirical, using estimates of soil properties; and (iv) process models, combining mapping with computer models such that dynamic processes can be simulated. The fourth approach is mechanistic and quantitative and is considered the *"best"* (McKenzie *et al.* 2008).

Demonstrating their lower-order approach, DERM (2011c, p.50) suggest use of a *"70/30 purity rule"*, ostensibly supported by McDonald (1975), for the purpose of delineating the spatial extent of any areas of SCL. Interestingly McDonald (1975) only recommends that map purity be recorded and this is consistent with McKenzie *et al.* (2008).

The objectives of the technical assessment (DERM 2011c) were to *'test that the criteria accurately define SCL, test that the threshold values are set at the appropriate level to identify SCL and make recommendations on the proposed criteria and thresholds'*. DERM's technical assessment is heavily reliant on the collective opinion and experience of the assessment team and appears overly subjective in nature. Examples of apparent subjectivity, unsupported by references or data, litter the report and include, amongst others, the following: (i) *"Decreasing the soil water storage threshold from 100 mm to 75 mm for the coastal zone to rectify the inappropriate exclusion of particular horticultural soils" (page 8);* and, (ii) *"...identified a number of sites on the Eastern Downs where long term and highly productive cropping is practiced" (page 21).* In both examples, criteria were amended to include cropping land believed by the assessment team to be SCL, but no rigorous assessment, data or justification was provided to support this conclusion.

In testing the proposed criteria and thresholds (DERM, 2011c), approximately 16% of all sites, i.e. at almost one in five sites, the methodology required further testing before a determination of SCL could be finalised.

In total, 128 sites were either tested by desktop assessment of existing data (74 sites), using the SALI data-base, or this plus a field component (54 sites). DERM (2011c) report that both testing methods were *"undertaken in the same manner"* and therefore, it could be assumed that results are consistent and comparable. But, this is not the case and results are starkly, and statistically, different if assessment methods are compared (Table 4). This effect was most significant in the Western zone where 26 sites had a field component and 28 did not. Analysis shows that if a desktop assessment was done without a field component, the site was three-times more likely to be identified as SCL within the Western zone.

This strongly significant effect of testing method should have been identified and explained in DERM (2011c), but it was not. This highlights two important considerations for other governments considering development of similar discriminatory methodologies, viz. (i) field survey is critical to accuracy; and, (ii) methods of testing need to be consistent.

Table 4. Tests of significant contrasts (Chi Squared - ***P≤0.001; **P≤0.01; *P≤0.05; ^P>0.05) between desktop and field assessment methods

Zones	Contrast	*P* value
All zones	Desktop - Field	*
Western	Desktop - Field	**

An analysis of proportions (Fisher Exact Probability test - Statistica v9.1) identified that each of the eight criteria was not equally effective when applied by DERM (2011c) to identify SCL (Table 5), particularly within the Western zone (Table 6). The criteria for rockiness, microrelief and soil depth were not useful as discriminators across all 128 sites. Within the Western zone, slope, rockiness, microrelief and soil depth were also significantly ineffective. While this effect may be an artefact of the site selection process, which was not random but targeted toward soils thought to be close to the threshold boundaries, it was neither identified nor investigated in DERM (2011c).

An additional, and widely used, statistical technique (Liu *et al.* 2005) for visualising, organising and selecting classifiers based on their effectiveness has been adopted (Figures 9 and 10). This further demonstrates that some criteria had no significant value as discriminators for identifying SCL.

The simple statistical analysis conducted here shows that criteria such as slope, rockiness, microrelief and soil depth were not effective. In contrast, DERM (2011c) make only a qualitative determination that *"criteria have been developed to reliably and consistently identify the state's best cropping land."*

Table 5. Tests of significant discrimination (Fisher Exact Probability - ***P≤0.001; **P≤0.01; *P≤0.05; ^P>0.05) between criteria for all 128 sites across all zones (data from DERM 2011c)

Criterion	Not SCL (count)	Possible SCL (count)	Effectiveness (%)	*P* value
		128		
1 Slope	13	115	10.2%	**
2 Rockiness	0	115	0.0%	^
3Microrelief	3	112	2.6%	^
4 Soil depth	5	107	4.5%	^
5 Wetness	14	93	13.1%	***
6 Acidity	12	81	12.9%	***
7 Salinity	14	67	17.3%	***
8 Water storage	11	56	16.4%	***
	19[1]	37[2]		

[1] undecided; [2] SCL

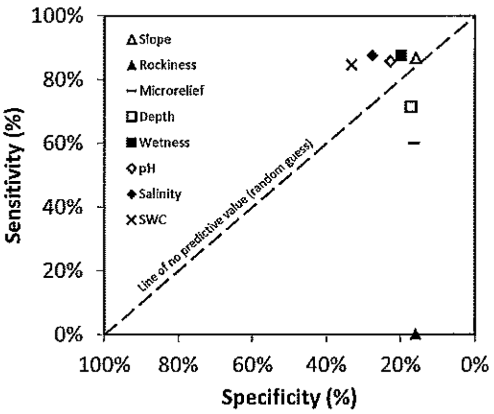

Figure 9. Binary classification model plotted in receiver operating characteristic (ROC) curve space, indicating relative predictive value of each criterion applied at 128 sites. Note the criterion below the line of discrimination have no predictive value in identifying SCL.

Table 6. Tests of significant discrimination (***P≤0.001; **P≤0.01; *P≤0.05; ^P>0.05) between criteria for sites within the Western zone only (data from DERM 2011c)

Criterion	Not SCL (count)	Possible SCL (count)	Effectiveness (%)	*P* value
		54		
1 Slope	2	52	3.7%	^
2 Rockiness	0	52	0.0%	^
3Microrelief	3	49	5.8%	^
4 Soil depth	0	49	0.0%	^
5 Wetness	2	47	4.1%	^
6 Acidity	6	41	12.8%	***
7 Salinity	12	29	29.3%	***
8 Water storage	7	22	24.1%	***
	6[1]	16[2]		

[1] undecided; [2] SCL

The statistical analysis conducted here demonstrates the value of a quantitative approach in evaluation of each criterion's usefulness, as opposed to the subjective approach in DERM (2011c).

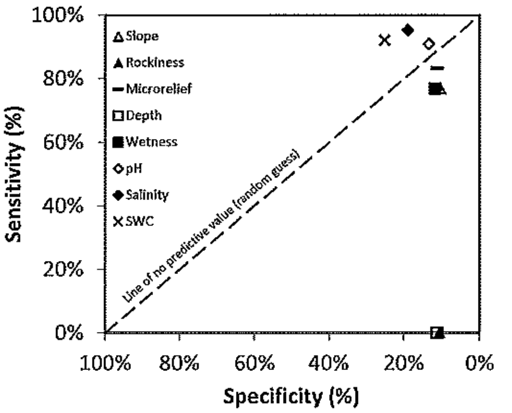

Figure 10. Binary classification model plotted in receiver operating characteristic (ROC) curve space, indicating relative predictive value of each criterion applied in the Western zone. Note the criterion below the line of discrimination have no predictive value in identifying SCL in the Western zone.

The testing reported in DERM (2011c), is clearly subjective, was not finalised at about one site in every five, and was strongly biased by assessment method, i.e. desktop or field. Further, several criteria were not significantly effective in identifying SCL. Therefore, on this quantitative basis, the scientific value of the technical assessment by DERM (2011c) is questionable.

Basis and usefulness. The eight criteria proposed by DERM (2011b) appear to have been derived from established land evaluation criteria in Queensland (DPI 1990). The current Queensland method (DPI, 1990) lists 17 criteria for plant growth and many additional criteria for machinery use, irrigation, grazing animals and control of land degradation. Limitations are assigned to each criterion, and via evaluation of criteria and limitations, a score or Suitability Class is determined (see Table 7).

Table 7. Land use suitability class definitions
(Source: DPI 1990)

Suitability Class	Description
Class I	Suitable land with negligible limitations
Class II	Suitable land with minor limitations
Class III	Suitable land with moderate limitations
Class IV	Marginal land, considered unsuitable
Class V	Unsuitable with extreme limitations

Consequently, the criteria and thresholds in DERM (2011b) can be 'cross-referenced', where possible, to recommended suitability limits for broadacre cropping in Queensland. In general, the nominated thresholds for each criterion relate to suitability Classes I, II, III and IV (refer Table 7 and Appendix A). This means that, effectively, the nominated thresholds risk including all land suitable for broadacre cropping as SCL.

Additional comment on each criterion's relevance to cropping in the Western zone and ability to discriminate SCL is provided below. This is provided despite the issues identified above: that several of the eight criteria may not prove to be effective discriminators (see Tables 5 and 6, Figure 9 and 10); and thresholds often appear to be related to Class III and IV soils rather than the better land associated with Classes I and II (see Table 7 and Appendix A).

1 Slope (≤3%). Slope is not one of the 17 limitations that affect plant growth, but is one of the twelve limitations listed for agricultural machinery use and also the default descriptor for the water erosion hazard limitation - one of six limitations for land degradation (DPI 1990).

As slope is the first of the criteria it should be, and is, easy to assess. However, while the threshold nominated by DERM (2011) of 3% across the Western zone may be appropriate for many soils, it is not considered appropriate for soils with more erodible subsoils, e.g. sodosols and kurosols (DME 1995). In these circumstances, the method relies on soils failing later criteria.

Further, DERM (2011c) identified *"a number of sites on the eastern Darling Downs where long term and highly productive cropping is practiced"* but provide no quantitative data to support this assertion. Yet, based on this observation and *'discussions'* during field assessment, it was proposed to demarcate a new zone called Eastern Downs, allowing up to 5% slope. In contrast, the current Queensland method (DME, 1995) classifies slopes of 5% as Class IV land, not suitable for sustainable cropping. This subjective approach, where land is observed to be cropped and therefore must be SCL, with thresholds amended without supporting data or references, is symptomatic of many key decisions presented in the technical assessment report, i.e. DERM (2011c).

On its own the threshold limit of 3% is not appropriate for all soil types within the Western zone, and relies on later tests to address this problem. As such it may not adequately discriminate SCL, and may result in classification of some areas as SCL which are not.

2 Rockiness (≤20% for rocks >60 mm diameter). Rockiness is a limitation assigned to a criterion for plant growth in the Queensland Land Suitability Guidelines (DPI 1990). The application of rockiness in land suitability assessment for broadacre cropping (DME 1995) indicates that the proposed threshold limit of *≤20% for rocks >60 mm diameter* includes Class IV for sorghum, maize, sugar cane, and sweet corn. Sorghum is a significant summer cereal crop in Queensland (> 400,000 hectares sown in 2005/2006 - ABS 2008a, with a gross value of more than $150M - ABS 2008b).

The rockiness threshold proposed by DERM (2011b) identifies Class IV land as SCL; land that is accepted by current methods to be unsuitable for growing sorghum (DPI 1990; DME 1995).

DERM (2011c) provide no new quantitative assessment or scientific reference for this criterion and threshold. Further, it is stated that only one of the 128 sites subjected to *'detailed checking'* failed this criterion. Despite the usefulness of this criterion and threshold limit being restricted to less than 1% of sites tested, DERM (2011c, p. 22) suggest, ambiguously, that it will be both *"not a major discriminator"* and *"it will be useful"*. No additional evidence is provided and the usefulness of this criterion for differentiating SCL is questionable.

3 Microrelief (<50% gilgai cover of >500 mm in depth). This criterion is not associated with plant growth; rather it is a limitation to one of the twelve criteria for agricultural machinery use (DPI 1990). Ordinarily, assessment of this limitation is an economic consideration related to the cost remedial earthworks required to prepares the land for cultivation (DPI 1990).

If land is already cultivated, either it has previously been levelled or did not require levelling. So, where cultivation exists, the microrelief criterion will not apply and will not further discriminate between SCL and non-SCL. This particular limitation only has relevance to land that has never been cultivated.

DERM (2011c) provide no quantitative assessment nor published references to support this criterion and threshold. Further, it is stated that only three of the 128 sites subjected to *'detailed checking'* failed this criterion. Despite the usefulness of this criterion and threshold limit being restricted to less than 3% of sites tested, DERM (2011c) concluded that the criterion was appropriate, based on *"experience"* and *"observation"*. Further, the threshold level was increased from 300 mm to 500 mm solely based on the *"teams"* experience (DERM 2011c).

As the basis to this criterion and threshold is wholly subjective, and it is not applicable to land that is already cultivated, its usefulness in discriminating SCL, particularly from other cultivated land, is questionable.

4 Soil depth (≥600 mm). In typical land evaluation, this criterion is only assessed in relation to the depth of soil required to provide physical support to plants and is *"only applied in cases where a crop requires a depth of soil for physical support which is greater than that required for water or nutrient supply....such as tree crops"* (DPI 1990). In this context, the nominated threshold of ≥600 mm soil depth, may or may not be reasonable for the Western zone if plantation forestry is being considered, but is entirely irrelevant to broadacre cropping.

Even if soil depth is measured and assumed to be adequate for broadacre cropping, Dang *et al.* (2004) demonstrate that the presence of subsoil constraints including sodicity and salinity in the cropping soils of central and southern Queensland, acidity in Brigalow soils, and sodicity in central

Queensland, can limit crop yield by reducing the depth of soil able to be explored by crop roots.

Dang *et al.* (2004) also showed that strong subsoil sodicity and high salinity may be present in 38% and 26%, respectively, of the cropping soils in southern and central Queensland. The effect of these subsoil constraints is to restrict the proliferation of roots to a depth less than the total soil depth, prohibiting crop roots from accessing stored water and nutrients below this depth. The depth of soil available for root proliferation is known as the *effective rooting depth.*

DPI (2006) state that for cropping soils of central Queensland the effective rooting depth must be at least 600mm to 1200mm, minimum, depending on the soil type.

Although this criterion may be easy to measure, as required by DERM (2011b). The direct relevance of total soil depth to SCL is unsupported. Although its primary value appears to be in filtering out soils that are too shallow for effective cropping in each of the respective zones, for example as an easy-to-measure surrogate for more complex parameters such as effective rooting depth or plant available water. However, it will have a high degree of error due to the widespread occurrence of subsoil constraints within the Western zone (Dang *et al.* 2004). As such, this criterion will only be able to discriminate very shallow soils from SCL and it will not accurately discriminate SCL from other land when the soil depths exceed 600 mm. In this case later criteria will be relied upon.

For relevance, Dalgliesh and Foale (1998) assessed more than 60 cropped vertosol soils in Queensland and reported the mean soil depth to be 1200 mm, ranging from 600 mm to 1800 mm. This quantitative evidence demonstrates that the threshold limit proposed by DERM (2011b) is at the lower limit for cropping soils and will not be an efficient criterion, having a propensity for inclusion of all cropping land rather than differentiation of the *'best cropping land'.*

5 Wetness (has favourable drainage). This criterion relates to soil drainage, aeration and waterlogging, and is a limitation affecting plant growth (DPI, 1990). A basis for the threshold descriptions is found in McDonald and Isbell (2009).

McDonald and Isbell (2009), commonly referred to by soil scientists as the *'yellow book'*, describes wetness categories as *"very poorly drained, poorly drained, imperfectly drained, moderately well drained, well drained and rapidly drained"* and offers explanatory commentary for each. The value of new terminology in DERM (2011b) is questionable.

While this criterion may be assessed easily in the field if waterlogged soil is clearly present, a level of expertise is required to interpret the mottles and soil colours used to identify the drainage limitation of a drier soil. This expertise is of increasingly limited availability (Craemer & Barber 2007). Consequently this criterion may not always be readily assessed in the field with confidence and therefore, its usefulness in differentiating SCL is questionable.

6 Soil acidity (For non-rigid soils, the soil at 300 mm and 600 mm soil depth must be greater than pH 5.0; For rigid soils, the soil at 300 mm and 600 mm soil depth must be within the range of pH 5.1 to pH 8.9). Soil acidity, or pH, is not a criterion for plant growth (DPI 1990) but is a partial descriptor for the nutrient availability limitation (DME 1995). The basis for the nominated criterion thresholds is not supported by published literature.

The optimum range of pH for all major tropical crops, including wheat and sorghum, is between 5.5 and 8.5 (Landon 1984). While more recent studies considering Australian soils and production systems (Peverill *et al.* 1999) have shown crop tolerance to pH as low as 5.0 they recommend that amelioration of these soils is necessary if productive yields are to be maintained.

Lime application may address pH issues in some circumstances and DERM (2011b) state that *"standard agricultural practices"* include lime application for pH amendment. In contrast, ANRA (2009) state that lime application in broadacre dryland farming is generally neither practical nor economical.

It could be assumed that the best cropping soils would have a pH within the optimal range of 5.5 to 8.5, rather than that proposed by DERM (2011c).

In the Western zone, only one of 54 sites subjected to *'detailed checking'* failed this criterion (DERM 2011c). Despite the usefulness of this criterion and threshold limit being restricted to less than 2% of sites tested in this zone, DERM (2011c) recommend the criterion and thresholds for discriminating SCL from non-SCL.

7 Salinity (Chloride content <800 mg/kg within 600 mm of the soil surface). This limitation typically relates to mean salinity within the effective rooting depth (DPI 1990). In contrast, the salinity threshold nominated by DERM (2011) includes an unexplained depth constraint of 600 mm. This is inconsistent with the approach by DPI (1990) and its inclusion warrants a more detailed and supported justification in the assessment report.

Salinity is an important issue. Gardner *et al.* (1988) estimate that 1.2 million hectares of vertosols are used for cropping in Queensland and DPI (2006) and Dang *et al.* (2004) demonstrate that within much of the Western zone, the effective rooting depth of these vertosols is affected by salinity. Therefore, measuring soil salinity accurately within the effective rooting depth, in accordance with DPI (1990), is critical in discriminating SCL from other land in the Western zone.

8 Soil Water Storage (≥100 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm). The capacity of a soil to store water that is later available to a crop is a fundamental component of successful cropping in Queensland (Freebairn *et al.* 1990). DERM (2011b, 2011c) provide a *"look-up-table"* as a basis for determining Soil Water Storage (SWS) in the field. The SWS is effectively the plant available water capacity (PAWC) of the soil to 1000mm soil depth.

The "*look-up-table*" was developed by the "*accumulated knowledge*" of the assessment team and provides an estimate of the SWS for a range of soil textures, but does not include a specific reference to cracking clays as other authors do (e.g. McKenzie *et al.* 2008). The technical assessment report notes that "*they* [the team] *do not attempt to capture the range of experimentally measured soil water storage values*" (DERM 2011c, p35). These values are also described by the assessment team as closer to the lower end of soil water storage ranges for texture classes (DERM 2011c, p34). This may explain why these values are in stark contrast with a similar table in the current Australian guidelines for surveying soil and land resources (McKenzie *et al.* 2008, p476) which includes specific values for cracking clays.

DERM (2011b, 2011c) nominate a threshold limit of ≥100 mm for SWS in the western zone, with reference to specific research and data, e.g. Shaw and Yule (1978), Gardner and Coughlan (1982) and Dalgleish and Foale (1998).

The assessment team applied an allowance of ±15% when assessing the SWS criterion using the "*look-up-table*", apparently to accommodate the approximate nature of the approach. For example, a Western zone soil would need to have a SWS of less than 85mm to be ruled out as SCL, or more than 115mm, to be deemed SCL. For soils between 85 and 115mm further testing would be required. The reason for allowing a further 15% below the threshold when the table was established using low estimates of PAWC is not explained. Perhaps a clearer way of explaining this approach is that it is equivalent to a threshold of 115mm, with an allowance of -25% triggering further testing.

However, many authors suggest a minimum PAWC, over any depth of soil in the Western zone, of 120mm or more. For example, Biggs (2007) emphasises that the capacity of a soil to store water, and the ability of a crop to extract water, are key constraints to cropping in Queensland. Whereas, DPI (2006) states that the suitability of soils for cropping in central Queensland is determined by their surface and sub-surface properties, fertility and water holding capacity, and that not all of the wide range of soils present can be cropped.

A key message of DPI (2006), who studied cropping soils within the Western zone in central Queensland, is that soils need to be able to store at least 120 mm of plant available moisture in the effective rooting depth for reliable rain-fed cropping. Given that the effective rooting depth is commonly limited to between 800mm and 1000 mm, due to salinity and/or sodicity (DEEDI 2006), these soils must be able to store more than 120 mm of water in the effective rooting depth - the surface 800mm to 1000 mm of soil.

The SWS values in DERM (2011c) are inconsistent with those in DPI (2006) and McKenzie *et al.* (2008), and considerably lower than those presented by many other authors, viz. (i) Shaw and Yule (1978) measured PAWCs in the Emerald irrigation area during the 1973 and 1974 seasons and report PAWCs of 70mm to 195mm (or 11.5mm and 21.6mm per 100mm layer of soil); (ii) Gardner and Coughlan (1982) working in the Burdekin irrigation area report PAWCs of 51mm to 158mm (or 8.6mm to 19.8mm per 100mm layer); and, (iii) Dalgleish and Foale (1998) studied varied locations and report PAWCs of 109mm to 288mm (or 6.1mm to 19.3mm per 100mm layer). Further, using the look-up-table in DME (1995) to calculate a PAWC of only 100mm, equates to a SWS of 16.7mm per 100mm layer of soil.

Numerous authors provide PAWCs for different soil types (see Table 7). This data shows that for a 1000 mm soil profile, only very sandy soils would fail to meet the soil water storage threshold nominated by DERM (2011b).

Many previous attempts have been made to estimate soil moisture using similarly subjective methods to derive 'look up tables', e.g. Northcote *et al.* (1968); McKenzie and Hook (1992); and, McKenzie *et al.* (2003). McKenzie *et al.* (2003) say such tables have many limitations and could be greatly improved through careful data interpretation in conjunction with more modern, quantitative land evaluation methods, i.e. mechanistic or modelling approaches.

Consequently, '*look-up-tables*' are considered a last resort with many limitations (McKenzie *et al.* 2003). Such tables are examples of estimation in land evaluation that encourage uncritical thinking (as discussed in McKenzie and Cresswell, 2002). Disregard of quantitative soil physical characterisation in land evaluation is, perhaps, 'old fashioned' and based on practitioners' beliefs that direct measurement is time-consuming and technically demanding (McKenzie *et al.* 2002) and slow and costly (DERM, 2011c).

The approach adopted by DERM (2011c) relies on the use of an estimation technique that does not appear to include appropriate values or specific relevant values for cracking clay soils. Further, the values used are acknowledged as being low. These are significant issues as this is the last, and the most important of all the criteria, drawing into question its ability to discriminate SCL from other land.

Minimum area requirements (100 ha or greater and at least 80 metres wide). Although not listed as a 'criterion', DERM (2011b) stipulate a minimum land area and dimension for SCL identification. No basis, scientific or otherwise, is provided to justify this requirement. Size of resource is not independent of the production system it is within. For example, the size of viable dryland farms increases from east to west, as rainfall variability increases. Consequently the viable minimum size of SCL within any given property will increase. Contiguity of the SCL resource across property boundaries is a separate issue not discussed by DERM (2011c).

Table 7. Reported PAWC values for different soil texture classes

Soil texture characteristic	Typical soil classification	PAWC (mm/m)					
		DEEDI (2006)	Moore *et al.* (1998)	Williams *et al.* (1983)	Mullins (1981)	Burk and Dalgleish (2008)	Dalgleish and Foale (1998)
Coarse sand	Rudosol	35-60	20	--	--	--	--
Medium sand	Rudosol	60-75	40-50	--	--	50	--
Fine sand	Rudosol	--	50-70	--	--	--	--
Loamy sand to coarse sandy loam	Rudosol	75-160	110-220	160	--	80	--
Fine sandy loam	Kandosol	145-185	170-220	200	114	--	--
Sandy clay loam to coarse sand	--	--	120-180	120	--	120	--
Clay loam to light clay	--	170-250	130-190	240	--	--	--
Light to medium clay	Ferrosol	150-200	--	130	157	--	--
Medium clay	Vertosol	--	110-120	120	115	--	--
Medium clay to heavy clay	Vertosol	--	120-210	130	167	150-200	134

The minimum area requirement of 100 ha, equates to between 52% and 13% of property sizes within the Eastern Downs and Western zones (Table 9). This not only highlights the considerable dissimilarity in property sizes between regions but suggests the consequence of 100 ha of SCL protection or loss is also dissimilar between regions within the zone. As more grain producing properties are located on the Eastern Downs than any other region, and assuming that 100 ha is an appropriate and considered minimum requirement for SCL here, then this equates to a relative proportion to property size of 52%. To achieve similarity of consequence across regions, then the minimum size requirements would be 100 ha for the Eastern Downs, 239 ha for the Western Downs, 382 ha for Roma and 410 ha for Central Highlands.

Table 9. Mean property sizes – relative proportion of 100 ha
Information from ABS (2008a)

Region	Number	Size (ha)	100 ha / size ha
Eastern Downs	962 (48%)	193	52%
Western Downs	760 (36%)	461	22%
Roma	148 (07%)	738	14%
Central Highlands	233 (11%)	791	13%

Conclusions from review

DERM (2011b) provide a diagnostic tool, based on trigger maps, zones and criteria with thresholds, that is both simple and potentially cost-effective. However, in its current form, it is not likely to be effective and will not reliably discriminate SCL, because: (i) the broad-scale of the trigger maps will likely cause inaccurate triggering; (ii) the vast Western zone is not homogenous with respect to climate, soils and farming systems; (iii) the criteria and thresholds are ineffectual discriminators; and, (v) the criteria and thresholds tend to inclusion of all cropping land rather than differentiation of the "best".

The development and testing of the methodology was clearly subjective. Hajkowicz (2004) states that the use of subjective judgements in an evaluation exercise can create concerns over transparency and repeatability, and that finding technical experts who are free of bias is almost impossible.

The scientific value of the technical report (DERM 2011b), incorporating the findings of Shaw (2011), is limited and questionable.

A quantitative assessment of rainfall and PAWC limitations for rainfed cropping in the Western zone

Introduction

Rainfall and PAWC are recognised critical factors influencing cropping success in Queensland (Biggs 2007). The variability of rainfall has been shown to significantly affect wheat yields across Australia with Queensland showing the greatest variability due to the sub-tropical climate and rainfall regime (Russell 1984, Potgieter *et al.* 2002). To overcome this variability, cropping strategies have been developed that rely on optimising the use of stored soil moisture combined with in-crop rainfall (Freebairn *et al.* 1990).

This section considers the influence of rainfall and PAWC on rain-fed cropping success in the Western zone by applying quantitative land evaluation (QLE) using APSIM (Keating *et al.* 2003).

Materials and methods

The cropping systems model APSIM (Agricultural Production Systems Simulator) (Keating *et al.* 2003) is internationally recognised as a highly advanced simulator of agricultural systems. It contains a suite of modules which enable the simulation of systems that cover a range of plant, animal, soil, climate and management interactions. Unlike many systems models, APSIM is continually being developed and maintained by rigorous science and software engineering. The model is supported by the APSIM Initiative- a joint venture between the Commonwealth Scientific and Industrial Research Organisation (CSIRO), The University of Queensland (UQ), and the State of Queensland through its Department of Employment, Economic Development and Innovation (DEEDI). To date APSIM has been used in over 200 internationally published scientific journal papers covering issues associated with agricultural and cropping systems production including land use and soil and climate change impacts.

Within the QLE approach adopted QLE addresses issues that arise in land resource determinations by applying quantitative methods to reduce the subjectivity inherent in other approaches (Thomas *et al.* 1995; McKenzie *et al.* 2008; Ringrose-Voase 2008). Quantitative land evaluation is the analysis of land behaviour involving quantitative inputs and outputs. This includes analogues of conventional assessments as well as using simulation models (Ringrose-Voase 2008).

APSIM was used to simulate a series of cropping scenarios for a winter crop (wheat) and a summer crop (sorghum). These are the major crops grown in the Western zone (ABS 2008c). APSIM has been extensively validated for use in commercial wheat and sorghum cropping systems in Queensland (e.g. Meinke *et al.* 1997; Carberry *et al.* 2009; Hammer *et al.* 2010).

The scenarios were based on monocultures of each crop for different locations and soils, to provide an objective basis for reviewing the western-most extent to strategic cropping land, and the minimum PAWC for strategic cropping land in the Western zone. In the absence of a clear definition of SCL, the guiding principles in DERM (2011c) provide a basis for developing the QLE approach i.e. that SCL will need to be able to sustainably and reliably produce a range of crops without excessive inputs, soil conservation measures, or irrigation.

In addition to an adequate PAWC, sustainable rainfed cropping in the Western zone relies on maintaining soil organic carbon and nitrogen (Dalal and Mayer 1986a, 1986b, 1987). Typically, inputs of at least 40kg of nitrogen per hectare are required to balance losses in sustainable wheat cropping. This loss would be typically addressed through the application of fertiliser. To fully address it using green manure crops, such as legumes, would imply no harvestable crop in that season.

The approach adopted used the APSIM model to quantitatively establish the likelihood, or probability, of producing viable yields. To ensure that the complete relationship between climate, rainfall and predicted yield was generated for each crop type, the "*must plant*" switch was applied in the model. This ensured that a crop was planted every year. Under this control the model will plant using the planting rules within the nominated window if possible. Otherwise it will plant on the last day of the planting window.

The sensitivity of crop yield to agronomic factors such as variety and row spacing was also tested. These showed only marginal differences compared to average yields from simulations using the parameters presented in Appendix B. This was consistent with the results presented in agronomic trials (e.g. Spackman *et al.* 2001, , Whish *et al.* 2005, Collins *et al.* 2006) As such the parameters presented in Appendix B were used for all simulations presented in this paper.

Simulations were run using long term climate and rainfall records (maximum period of record available, often over 100 years) and current farming methods (Appendix B). Climate and rainfall files were developed from Bureau of Meteorology (BOM) records for each site with any missing values for solar radiation, evaporation, or maximum and minimum temperatures being replaced with average monthly values from BOM data. To provide the maximum length of record reasonably possible for a site, rainfall files were combined for nearby sites, e.g. Emerald post office and aerodrome. Any missing rainfall data within these records was assumed to be zero. Early years of record (1800's) where recording appeared unreliable, were not used, nor estimated.

APSIM was used to quantitatively consider two separate issues, viz. (i) the western-most extent of strategic cropping; and, (ii) establishing the relative importance of PAWC to cropping within different regions in the Eastern Downs and Western zones (e.g. eastern, southern and western Darling Downs, Maranoa and central Queensland.

Cropping success was determined by comparing modelled yields to breakeven yields for wheat and sorghum. These breakeven yields were derived from published trial results, gross margin analyses, and the farm-gate commodity price averaged over 10 years. These yields consider the costs of all inputs required for long-term sustainable cropping, where the costs of necessary inputs and management for sustainable production are included. Amounts for profit were not included in the calculation. Grain prices of $290 and $220 per tonne were applied for wheat and sorghum respectively. These were derived from average actual and forecast prices covering the period from 2006-2015 (Fell *et al.* 2010).

Corresponding breakeven yields for wheat and sorghum are approximately 1.5 t ha^{-1} (GRDC 2010) and 3.0 t ha^{-1} (Wylie 2008; Pacific Seeds 2008), respectively. Interestingly Gardner *et al.* (1988) reported a breakeven yield for wheat of 1.4 t ha^{-1}. More recently Wang *et al.* (2009) applied a QLE approach and APSIM to wheat cropping within the Murray Darling Basin and identified that the extent of cropping was associated with at least 160 mm growing season rain, yields of 2.5 t ha^{-1}, and gross margins of $150 ha^{-1}.

Results

Reviewing the Western extent of SCL. Within the Western zone the effect of climate and rainfall on wheat and sorghum yield, independent of soil type, was investigated by simulating cropping on the same high PAWC soil (a black vertosol, APSIM no 016, PAWC = 319 mm) at each location along two west-to-east transects (Charleville to Toowoomba and Barcaldine to Rockhampton) and one south-to-north transect (Goondiwindi to Clermont) (see Figure 11).

Figures 12 and 13 present median sorghum and wheat yield against distance from west to east (longitude) and distance north to south (latitude) respectively. Each figure shows the effect of rainfall and climate independent of soil PAWC by using the high PAWC deep black vertosol (described above), and the effect of PAWC by using a soil with a PAWC similar to the predominant cropping soil of the area (Appendix C). Where no cropping soils were present in an area the cropping soil from the adjacent area was used.

Figure 12 shows the significant effect of climate, rainfall variability and soil type on yield across regions within the Western zone. It is expected that yield will become low and asymptotic toward the west as climate and rainfall becomes more limiting, and higher and asymptotic toward the east as soils become limiting. While this effect is apparent in the west it was not so apparent in the east. To simulate this "sigmoidal" relationship, a cubic function was used. This shows that, due to climate and rainfall alone, cropping is not consistently viable west of Miles for either wheat or sorghum, where the median yield is below the breakeven yield for both crops. This means that in 50% of years, sown crops, in any rotation would not be expected to breakeven. A similar analysis was done for the west-to-east transect Barcaldine-to-Rockhampton showing that Emerald also established a western limit to cropping for both wheat and sorghum. These results are largely consistent with the analysis of cropping statistical data in Figures 6, 7, and 8.

It should be noted that more typical reliability for a viable production system would be 70% rather than 50% (Pers. Com. EA Gardner, 2011). As such the analysis above is likely to be an overestimate of the western extent of SCL.

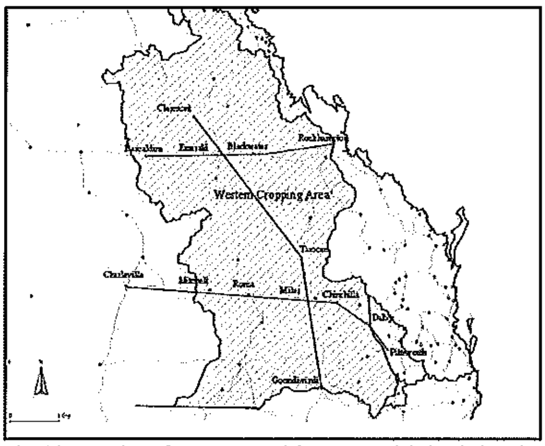

Fig. 11. Location of transects used for crop model simulations in APSIM.

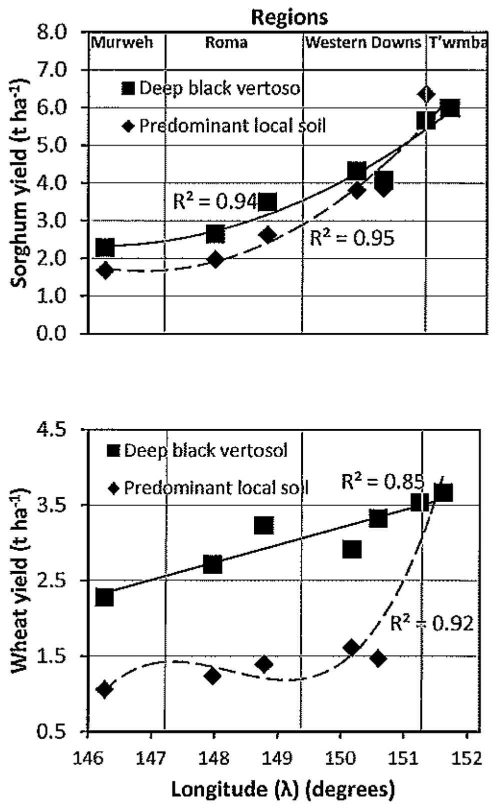

Fig. 12. Effect of climate on sorghum and wheat yields on a west-to-east transect within the Western zone.

In a similar analysis the effect of climate and rainfall, moving from south to north, shows that dryland wheat is not likely to be consistently viable north of Miles – effectively delineating the western-most and northern bounds of the Darling Downs.

Sorghum was less affected by changes in rainfall (Figure 13). However, the cooler climate combined with the local rainfall at Goondiwindi resulted in improved yields, compared with that at Clermont where greater in-crop rainfall could not counter the effect of increased temperature. The combination of poorer rainfall and increasing temperature suppressed sorghum yields in Taroom (Figure 13).

This study of climate and rainfall reflects conventional understanding that yields improve from west to east for both sorghum and wheat as more favourable rainfalls and climates are experienced. Similarly the south-to-north transect shows that median wheat yield decreases with increasing temperature and decreasing rainfall reliability. The study confirms the marginality of cropping west of Miles and Emerald. These locations are some 200 km east of the current proposed western cropping boundary in the SCL zone maps (Figure 5).

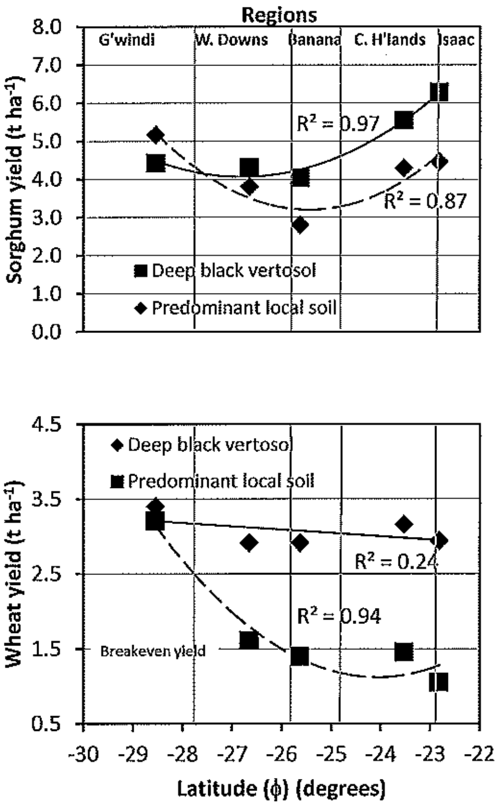

Fig. 13. Effect of climate on sorghum and wheat yields on a south-to-north transect within the Western zone.

PAWC - threshold analysis. The soil water storage criterion (criterion 8) has a threshold listed as ≥100mm over up to 1000mm of soil for the Eastern Downs and Western zones. The meaning and usefulness of this 100mm threshold value have been discussed earlier in this paper. This section considers what thresholds for PAWC are required for successful cropping in each district and then relates this to the SWS criterion.

Figure 14 compares the simulated wheat and sorghum yields for a range of PAWCs for a number of locations within the Western zone. Each location has a different climate and rainfall. This shows that that cropping success for wheat is more reliant on PAWC and stored soil moisture than is sorghum. This is most probably due to the summer dominant rainfall regime and a greater likelihood of substantial in-crop rainfall for sorghum. Comparison of these data to breakeven yields shows that PAWC's for successful cropping differ between locations. greater than 140 mm and 125 mm are important for successful wheat and sorghum cropping, respectively, within the Western zone (Figure 14).

Further quantitative analysis is possible to refine the estimates of threshold values for soil water content for different regions across the Western zone. For example, it is recognised that yield is affected by the amount of rainfall, its variability and PAWC. Figure 15 presents the results of a series of simulations for 12 different locations each with a range of different soils and PAWC's across the Eastern Downs zone and the Western Zone. The results show the relationship between modelled wheat yield, median rainfall, rainfall variability index (RVI = (P90-P10/P50), and PAWC.

Functions of PAWC and rainfall, and PAWC and RVI, have also been examined, viz.

$$\mathcal{F}1 = \frac{PAWC\ (mm)}{Median\ annual\ rainfall\ (mm)}$$

$$\mathcal{F}2 = \frac{PAWC\ (mm)}{RVI}$$

Correlations between wheat and sorghum yield and $\mathcal{F}1$ and $\mathcal{F}2$ are also presented (Figures 15, 16, 17 and 18).

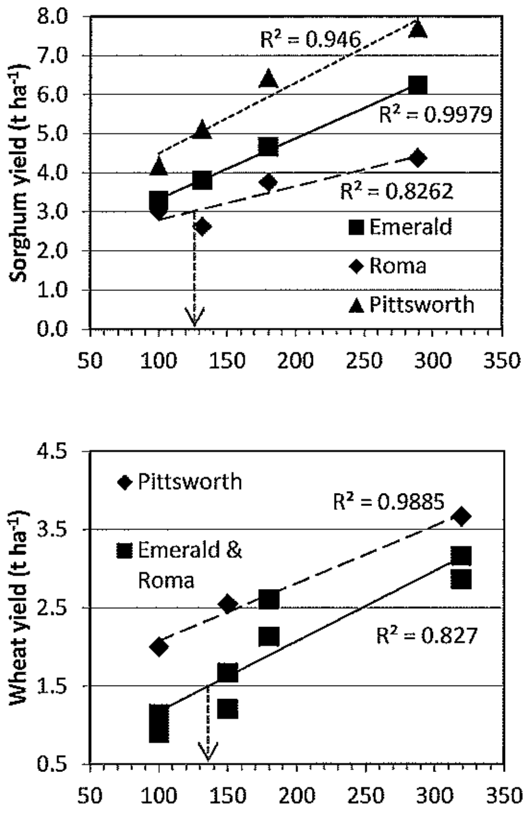

Fig. 14. Effect of PAWC on sorghum and wheat yields within the Western zone.

There is a highly significant relationship between yield and median rainfall for sorghum (Figure 17 and Table 14), but a poor relationship between wheat yield and median rainfall (Figure 15 and Table 11). This is consistent with the dependence of wheat on PAWC and stored moisture from a summer fallow, and the greater reliance of sorghum on in-crop summer rainfall. Similarly RVI was also highly negatively-correlated with sorghum yield (Figure 17 and Table 14) but also significantly negatively-correlated with wheat yield (Figure 15 and

Table 11). The sorghum being more affected by the variability of summer in-crop rainfall and wheat more dependent on the PAWC.

For both wheat (Figure 15) and sorghum (Figure 17) there are highly significant relationships between yield and $\mathcal{F}1$ and $\mathcal{F}2$.

A more detailed study of the data using General Linear Models (Statistica v9.2) showed that $\mathcal{F}2$ was the most powerful independent variable, explaining the most variation for both wheat and sorghum yield ($P<0.001$ for both wheat and sorghum). Consequently $\mathcal{F}2$ was used to further investigate the relationship between PAWC and location.

Each of the 12 locations were grouped into their respective regions (Roma, Central Highlands, Western Downs and Toowoomba), the relationship between yield and $\mathcal{F}2$ for each region was highly significant for wheat (Figure 16 and Table 12). The results for sorghum, while still significant, were less consistent (Figure 18 and Table 15), reflecting the lesser effect of PAWC on sorghum yield.

A covariance analysis (Statistica v9.1) identified that there was a significant effect of region on the relationship between yield and $\mathcal{F}2$ for both wheat and sorghum ($P<0.001$ for both wheat and sorghum). Tables 13 and 16 (wheat and sorghum respectively) provide detailed analysis of specific contrasts between each region. All contrasts were significantly different. Consequently, it may be concluded that the Western zone is different from the Eastern Downs zone, and the Western zone could be reasonably split into smaller more homogeneous regions with specific soil water content thresholds for the purposes of determining SCL. From the regression analysis and $\mathcal{F}2$ it is possible to estimate critical PAWC thresholds for each region (see Table 17). The original threshold suggested for the soil water content criterion of 100mm appears only to be justified in the Eastern Downs zone.

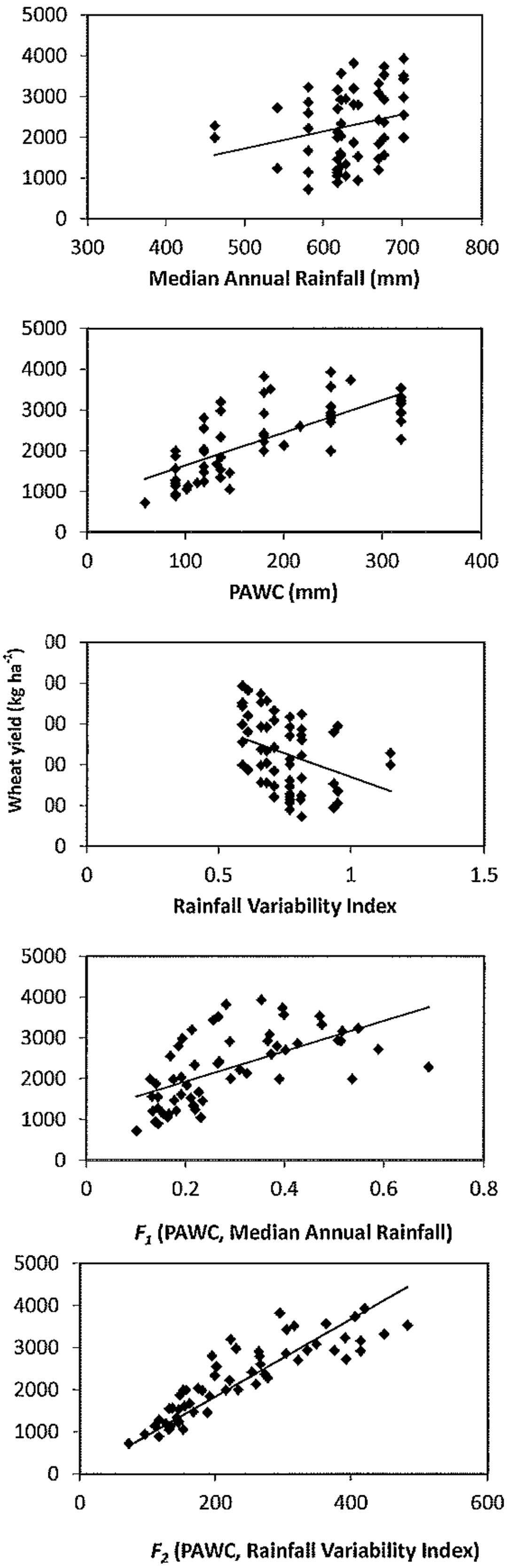

Fig. 15. Effect of median annual rainfall, PAWC, rainfall variability index, F_1(PAWC, median annual rainfall) and F_2 (PAWC, rainfall variability index) on modelled wheat yield

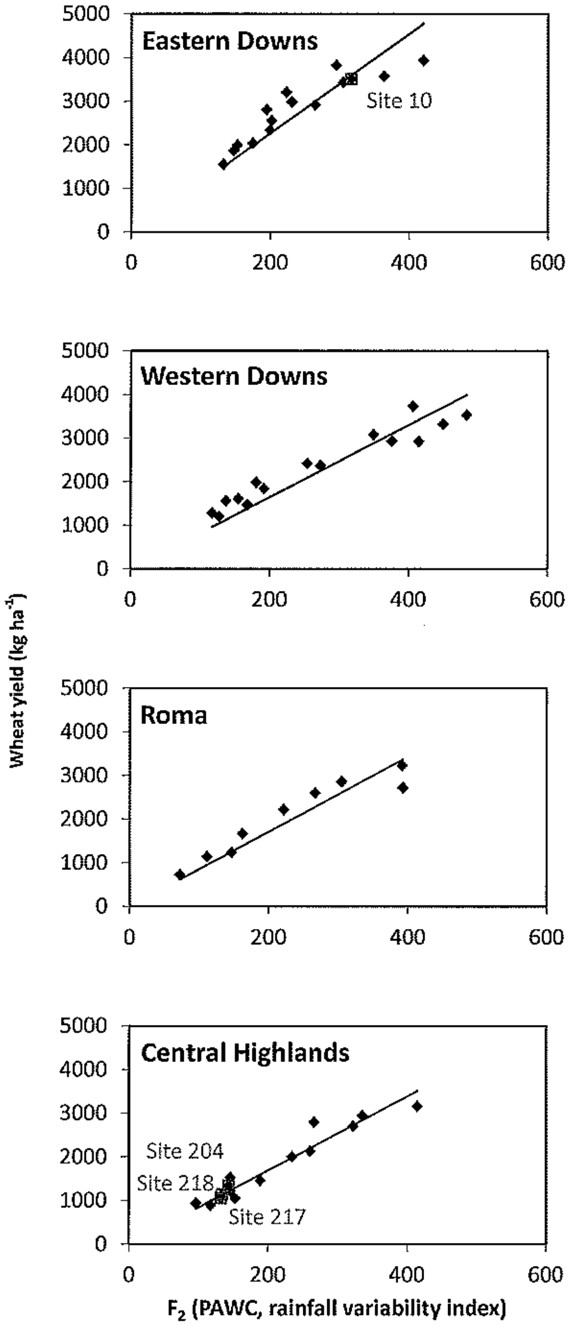

Fig. 16. Effect of F_2 (PAWC, rainfall variability index) on modelled wheat yield for each region. ☐indicates soil from Government's SALI database also used in DERM (2011c).

Table 11. Linear regression coefficients, tests of significance (*P≤0.001; **P≤0.01; *P≤0.05;^P>0.05) and coefficients of variation for changes in wheat yield versus median annual rainfall, rainfall variability index, PAWC, F(PAWC, median annual rainfall) and F(PAWC, rainfall variability index) (see Figure 15)**

Variable	*P* value	Intercept	Slope	R^2
Median rainfall	^	-350	4	0.07
Rainfall variability index	**	4,023	-2,324	0.13
PAWC	***	843	8	0.52
F (PAWC, median rainfall)	***	1,188	3,717	0.36
F (PAWC, rainfall variability index)	***	521	7	0.77
F (PAWC, rainfall variability index)	***	0.0	9	0.71

Table 12. Linear regression coefficients, tests of significance (*P≤0.001; **P≤0.01; *P≤0.05;^P>0.05) and coefficients of variation for changes in wheat yield versus *F*(PAWC, rainfall variability index) and calculated minimum PAWC values to achieve median yield of 1500 kg ha⁻¹ within each region (see Figure 15)**

Location	*P* val.	Inter-cept	Slope	R^2	*PAWC range (mm)*
Eastern Downs	***	0.00	11.38	0.70	80 - 90
Western Downs	***	0.00	8.25	0.84	120 – 140
Maranoa	***	0.00	8.57	0.87	140
Central Highlands	***	0.00	8.47	0.93	140 - 170

Table 13. Tests of significant contrasts (*P≤0.001; **P≤0.01; *P≤0.05; ^P>0.05) between regions for wheat yield and F_2 (PAWC, rainfall variability index) (see Figure 15 and Table 10)**

Contrast	*P* value
Roma-Western Downs	***
Western Downs --Eastern Downs	***
Western Downs – Central Highlands	***
Maranoa – Central Highlands	***

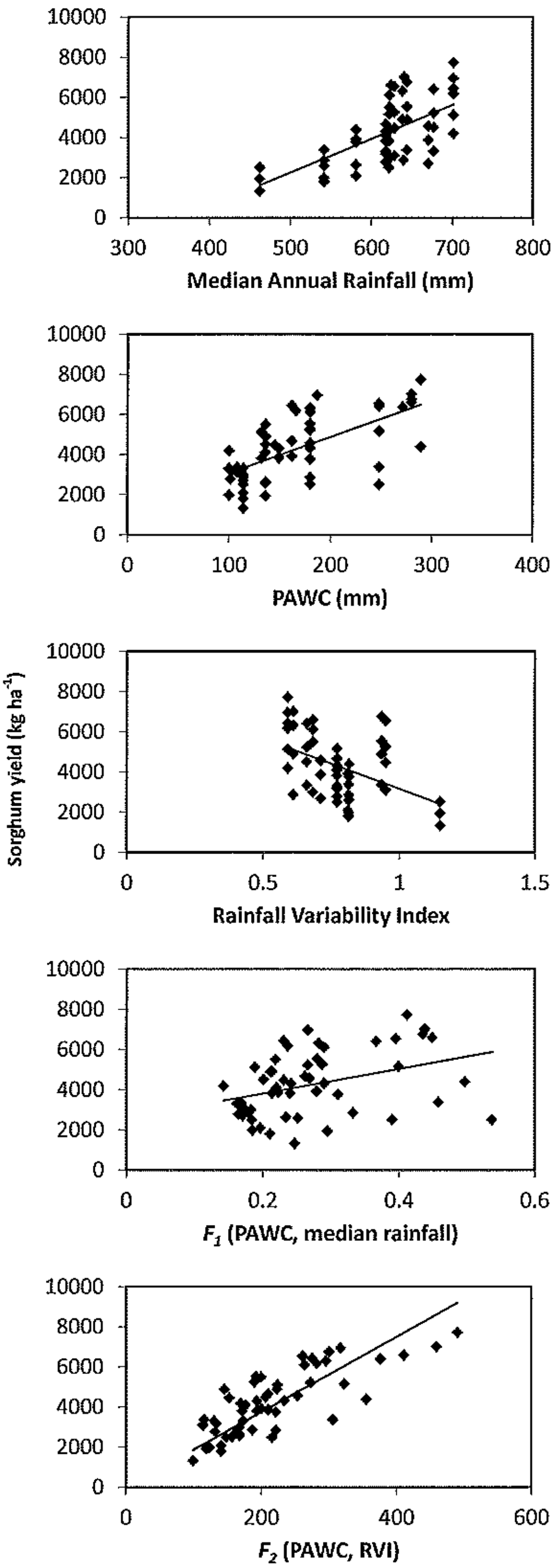

Fig. 17. Effect of median annual rainfall, PAWC, rainfall variability index, F_1 (PAWC, median annual rainfall) and F_2 (PAWC, rainfall variability index) on modelled sorghum yield

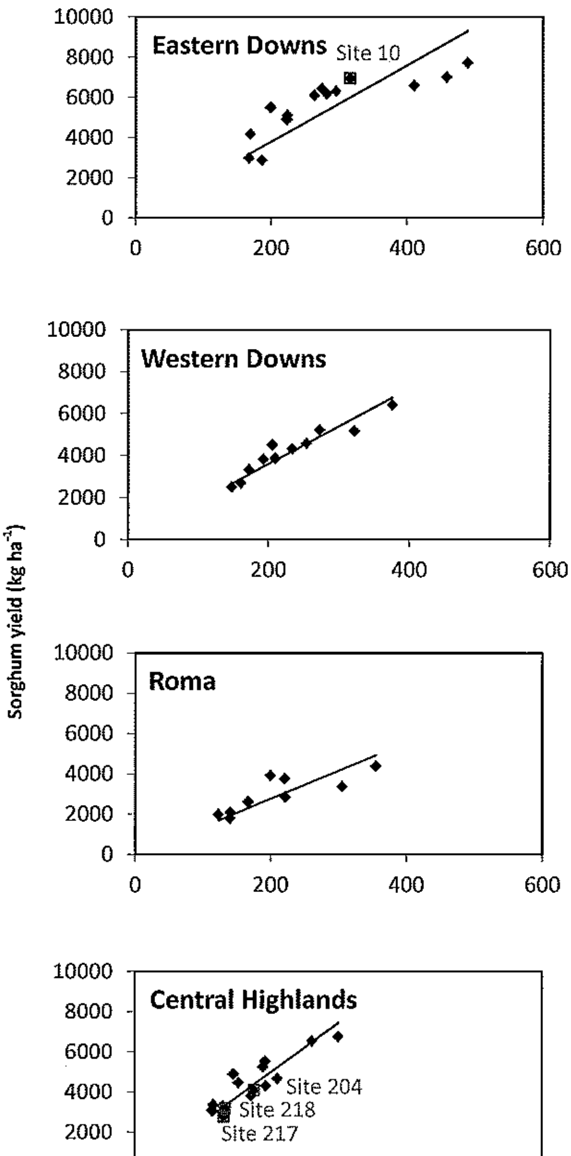

Fig. 18. Effect of F_2 (PAWC, rainfall variability index) on modelled sorghum yield for each region. ☐ indicates soil from Government's SALI database also used in DERM (2011c).

Table 14. Linear regression coefficients, tests of significance (*P≤0.001; **P≤0.01; *P≤0.05;^P>0.05) and coefficients of variation for changes in sorghum yield versus median annual rainfall, rainfall variability index, PAWC, F(PAWC, median annual rainfall) and F(PAWC, rainfall variability index) (see Figure 16)**

Variable	*P* val.	Inter-cept	Slope	R^2
Median rainfall	***	-6,128	16	0.43
Rainfall variability index	***	1,267	18	0.42
PAWC	***	8,129	-4,985	0.22
F (PAWC, median rainfall)	**	2,576	6,154	0.14
F (PAWC, rainfall variability index)	***	1,093	14	0.62
F (PAWC, rainfall variability index)	***	0.0	18	0.56

Table 15. Linear regression coefficients, tests of significance (*P≤0.001; **P≤0.01; *P≤0.05;^P>0.05) and coefficients of variation for changes in sorghum yield versus *F*(PAWC, rainfall variability index) and calculated minimum PAWC values to achieve median yield of 1500 kg ha^{-1} within each region (see Figure 17)**

Location	*P* val.	Inter-cept	Slope	R2	PAWC range (mm)
Eastern Downs	*	0.00	18	0.39	95 - 110
Western Downs	***	0.00	17	0.89	110 - 130
Maranoa	**	0.00	13	0.56	180
Central Highlands	***	0.00	24	0.77	95 - 115

Table 16. Tests of significant contrasts (*P≤0.001; **P≤0.01; *P≤0.05; ^P>0.05) between regions for sorghum yield and F_2 (PAWC, rainfall variability index) (see Figure 17 and Table 12)**

Contrast	*P* value
Roma-Western Downs	***
Western Downs –Eastern Downs	***
Western Downs – Central Highlands	***
Maranoa – Central Highlands	***

Table 17. Proposed demarcation boundaries and SWS criteria thresholds for seven regions within the Western zone

Region	PAWC (mm / m)	Minimum land area (ha)
Eastern Downs	≥ 100	100
Western Downs	≥ 120	239
Roma	≥ 175	382
Central Highlands	≥ 135	410
Goondiwindi	To be determined	
Banana	To be determined	
Isaac	To be determined	

Conclusions from modelling

This application of quantitative modelling and analysis demonstrates how the semi-empirical approach used by the assessment team could have been augmented, particularly for the critical soil physical thresholds associated with PAWC and SWS.

Furthermore, this analysis identifies that the western extent of strategic cropping land is likely to lie south-to-north along a line just west of both Miles and Emerald. The minimum threshold PAWC varies between crops and location but should not be less than 120 mm for cropping within the Western zone. The threshold value of 100 mm is identified as only being appropriate for the Eastern Downs zone, with specific thresholds applying to other regions within the Western zone ranging from (100 to 175mm for sorghum, and 120mm to 170 mm for wheat).

Discussion and conclusion

The general methodology of applying a trigger map to broadly identify areas of potential SCL, followed by the use of on-ground testing against discriminatory rules is a common approach to land use planning (e.g. local government planning schemes). These approaches rely on the appropriateness of the trigger maps for their intended purpose and the effectiveness of the rules *'triggered'* to guide the development assessment process. Consequently the success of this approach when applied to SCL is contingent on the adequacy of the criteria to discriminate the best cropping land from other land. Simplicity and efficiency of process, while commendable, should be secondary considerations and should not compromise effectiveness.

This review, and application of quantitative land evaluation methods, demonstrates that the proposed methodology for identification of SCL in Queensland has significant deficiencies. These deficiencies are likely to prevent the efficient and effective identification of SCL, risking Government's policy objective to conserve and manage the resource for the longer term, at considerable cost to industry.

Definition of SCL

The absence of a clear definition of SCL has affected the transparency around derivation of criteria and the setting of thresholds.

While there are guiding principles in place these are not sufficiently specific to provide the necessary clarity. For example, if the strategic cropping land is to be protected for the purpose of ensuring food production, then the expected frequency of successful cropping should be nominated. Concepts of frequency have been discussed in the development of the criteria but no final conclusions were reached. DERM (2011d) refer to a frequency of only three years in a period of twelve years as being a determining factor. This is much less than the median yields used in this review or the more typical business models requiring a reliability of seven years in ten (Pers. Com. EA Gardner, 2011).

It is not appropriate for the criteria that identify SCL to be said to define SCL. There is a dangerous circularity in this argument that the logic of classification strives against. For example, as knowledge about the effectiveness and efficiency of the criteria develop through application they are likely to be changed or at least refined as suggested in the concluding remarks of Shaw (2011). This would mean that the definition of what was meant to be SCL would also have to change.

A clear definition of SCL is essential to developing efficient and effective criteria and thresholds for its identification.

Trigger maps

The trigger maps (Figure 1) are based on reconnaissance-scale land survey information and are not recommended for use at a property-scale (DERM 2010e; McKenzie *et al.* 2008). As the purpose of trigger maps is to identify sites for on-ground assessment, and it is likely that these sites will be at a property-scale, the ability of the trigger maps to reliably initiate on-ground assessment for SCL identification is questionable.

Without either further refinement or clear guidelines for application, it is likely that inaccurate *'triggering'* will occur, leading to either the inconsequential assessment of SCL on non-viable cropping land or, more crucially, no assessment of SCL on some of the *"best"* cropping land.

For the mining sector, determination of SCL will be made as early as possible during the tenure application process (DERM 2010b), perhaps at tenure application stage. This will precede current *'triggers'* for an environmental impact statement (EIS). This is rather inopportune, as the level of accuracy currently required for soil and land evaluation in mining EIS submissions is more than three orders of magnitude more accurate than the trigger maps.

Zones

DERM (2010d) imply the zones group similar climates, soils and cropping types. This is not the case; at least not within the vast Western zone where strong trends in climate variability (Figure 6), crop yield (Figure 7) and landuse (Figure 8) exist.

Through the application quantitative land evaluation techniques, this study provides evidence that climate and soils are significantly different between key regions within the Western zone, viz. Eastern Downs, Western Downs, Roma and Central Highlands. Due primarily to rainfall variability, soil water storage requirements for viable crop yields are significantly different between regions (Figures 15, 16, 17 and 18). It is highly likely that further assessment would quantify similar variations for remaining regions within this zone i.e. Goondiwindi, Banana and Isaac.

This quantitative analysis shows that the efficiency and effectiveness of SCL identification would be improved by splitting the vast Western zone into smaller zones, potentially based on local government region boundaries (seven regions). It also shows that the western extent of SCL is most likely some 150 - 200 km further eastward than is currently suggested by DERM (2011c).

Criteria and thresholds

The eight criteria nominated by DERM (2011b) (Table 1) are a narrow selection of land suitability descriptors typically used in land evaluation (e.g. DPI, 1990). No explanation of the basis of selection of criteria is provided, beyond the experience of the expert assessment team. While the notion of a small set of simple criteria is commendable, for expediency and cost of assessment, this cannot be a higher priority than effectiveness.

The approaches used to develop and test the criteria and thresholds appear to be reliant on expert opinion, estimations and *"rules of thumb"* (DERM, 2011b, 2011c). There is little discussion and analysis or relevant scientific literature presented to justify the conclusions of the assessment team. Such analysis would have greatly improved the process allowing stakeholders a greater ability to understand key decisions relating to criteria and thresholds. This lack of rigor in the approach taken is consistent with the semi-empirical qualitative approach adopted. This style of approach relies on practitioner's understanding and *experience* (McKenzie *et al.* 2008. It is, however, inconsistent with current trends towards more transparent, reliable, mechanistic and quantitative approaches being encouraged since the 1980's in applied soil science for land evaluation, e.g. the use of quantitative modelling to augment soil survey (McKenzie *et al.* 2008).

In testing the proposed criteria and thresholds (DERM, 2011c), the *"experienced team"* were not able to decide SCL at approximately 16% of all sites, i.e. almost one in five sites could not be decided without further laboratory tests. Such testing is relatively expensive and care will have to be taken in designing the on-ground SCL identification programs so that costs of compliance are contained.

The 128 sites tested by DERM (2011c) were selected subjectively, ostensibly to trial criteria and threshold limits. In such a trial, it may be anticipated that about half the sites would pass and half would fail. Interestingly this was not the case. Firstly, the sites were either tested by desktop assessment of existing data (74 sites) or this plus a field component (54 sites). DERM (2011c) report that both testing methods were *"undertaken in the same manner"* and therefore, it could be assumed that results are consistent. But, this was not the case and results are starkly and statistically different. In the Western zone, 26 sites had a field component and 28 did not. Analysis shows that if a desktop assessment was done without a field component, the site was three-times more likely to be identified as SCL. This strong effect of testing method should have been identified and explained by the original authors of DERM (2011c) or their reviewer (Shaw, 2011) but it was not.

During the course of the technical assessment (DERM 2011c), some thresholds were changed based on subjective decisions to include existing cropping land perceived to be SCL without the presentation of data or research to support the decision, e.g. the soil depth threshold for the Coastal zone, and the slope threshold for the Eastern Downs zone.

However, the greatest shortcoming of DERM (2011b, 2011c) relates to the soil water storage (or PAWC) threshold limit within the Western zone. DERM (2011b) propose a soil water storage threshold limit of *≥100 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm* for the vast Western zone of almost half a million square kilometres. DPI (2006) recommend at least 120 mm PAWC for viable cropping in the Central Highlands region of the Western zone, other authors recommend similar thresholds for other areas within the zone – e.g. Thomas *et al.* 1995. The application of quantitative techniques (QLE) demonstrated that the proposed threshold limit of *≥100mm* is only viable in the Eastern Downs region. Minimum soil water storage requirements for viable cropping are significantly different between regions within the Western zone, viz. Eastern Downs ≥100mm, Western Downs ≥120mm, Roma ≥175mm and Central Highlands ≥135mm.

Quantitative assessment of data in the technical assessment report (DERM 2011c) shows that the eight criteria are ineffective discriminators of SCL (see Figures 9 and 10). Reasons for this may include the following: (i) threshold limits for criteria are too low to allow discrimination; (ii) certain criteria are not relevant to cropping, i.e. soil depth, or land that is already cultivated, i.e. microrelief; (iii) different testing methods have skewed results, i.e. desktop versus field (see Table 4); (iv) inconsistent application of criteria, e.g. for Site No. 53 soil water storage actually meets the threshold but is not classified as SCL (DERM 2011c, p.120); and, (v) the overall subjective semi-empirical approach adopted that was not supported by literature or quantitative methods.

The proposed criteria and thresholds are not effective and will not reliably discriminate the best cropping land from other land. The threshold limits are generally too low. This has two broad consequences; viz. (i) their usefulness is restricted to merely identifying land that is not suitable for viable farming, as opposed to distilling the *"best"* cropping land from all other, and (ii) any viable cropping land is generally identified as SCL.

Minimum Area

The final requirement, that any area of SCL must be a minimum of 100 ha, is not supported with any published literature or other reasoning in either DERM (2011b) or DERM (2011c). Objective analysis of property sizes, suggests that the consequence of 100 ha of SCL protection or loss is greatly different between regions within the Western zone. As more grain producing properties are located on the Eastern Downs than any other region, and assuming that 100 ha is an appropriate and considered minimum requirement for SCL in this region, then this equates to about 52% of typical grain property sizes. Given that property size is often linked to viability of each enterprise, the area of SCL required to be consequential in other areas may need to be greater. For example, to be of similar importance across regions, the minimum size requirements for SCL would be 100 ha for the Eastern Downs, 239 ha for the Western Downs, 382 ha for the Roma and 410 ha for Central Highlands (Table 14).

DERM (2011c) contains no discussion of property size and neglects to address how potential SCL should be considered across property and development boundaries.

Conclusions

This review and quantitative land evaluation study demonstrates that the proposed methodology for identification of SCL in Queensland is deficient and, in its current form cannot reliably identify the best cropping land. It may however, be able to identify areas of non-SCL reliably.

To develop the criteria and thresholds the Government adopted a semi-empirical approach, which is recognised as being subjective and prone to implicit biases. Since the 1980's soil science has been recommending a greater use of more robust quantitative methodologies in both soils survey and land evaluation e.g. modelling (McKenzie *et al.* 2008).

The trigger maps will not reliably initiate on-ground assessment because of their reconnaissance-scale basis. DERM themselves warn against the use of the maps at a property scale.

The Western zone is too large covering almost half a million square kilometres of Queensland, from the NSW border to about 1000 kilometres north. Quantitative assessment of key regions within this zone highlights significantly different climates, soil physical requirements for viable cropping and farming systems. Based on this evidence, the Western zone should be split into seven regions based on existing local government areas.

The eight soil-related criteria with thresholds are not effective and will not reliably identify SCL from other land. Primary deficiencies include: (i) the threshold limits are too low, restricting their usefulness to merely identifying land that is not viable cropping land, as opposed to distilling the *"best"* cropping land from all other; and, (ii) a lack of satisfactory explanation and scientific basis for the selection of the eight criteria.

The principle limitations to viable cropping in the Western zone are climate, rainfall variability and the capacity of soils to store moisture. The proposed methodology nominates a water storage requirement of *≥100 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm* within the

Western zone. This limit is entirely inadequate for viable cropping in all but one of the seven regions within the Western zone. New threshold limits for soil water storage should be determined by quantitative evaluation.

The proposed methodology must be improved through providing a clear definition of SCL, increased accuracy of mapping and, most importantly, adoption of modern quantitative land evaluation methods to develop and test key characteristics, i.e. criteria and threshold limits.

An effective outcome on this issue will require adoption of an inclusive approach by Government, as scientific knowledge, understanding and expertise of the issues surrounding SCL is likely dispersed within Government, academia and the private sector.

Acknowledgements

We wish to thank Professor Graeme Hammer and Professor Neal Menzies, both of The University of Queensland, for their independent and critical review of this paper and suggestions for improvement. We acknowledge the support of the Queensland Resources Council and also thank Mr Michael Roche and Mr Andrew Barger for their dispassionate resolve in pursuing a scientific basis for identification of strategic cropping land in Queensland.

References

ABS (2008a) Agricultural commodities: small area data, Australia, 2005-06 –all commodities Queensland (Reissue). Australian Bureau of Statistics - Publication No 71250DO014_200506

ABS (2008b) Agricultural commodities: small area data, Australia, 2005-06 (Reissue) – horticulture Queensland . Australian Bureau of Statistics - Publication No 71250DO017_200506

ABS (2008c) Agricultural commodities: small area data, Australia, 2005-06 – pastures and broad acre crops Queensland (Reissue). Australian Bureau of Statistics - Publication No 71250DO016_200506

ACLUMP (2009) Land use summary Queensland – state report. Australian Collaborative Land Use and Management Program

ANRA (2009) Soil acidification. Australian Natural Resource Atlas, Department of Sustainability, Environment, Water, Population and Communities - available at http://www.anra.gov.au/topics/soils/acidification/index.html. (accessed on 7 April 2011)

Biggs A (2007) The landscape and marginal cropping lands – inherent and induced. Tropical Grasslands, Volume **41**, 133-138

BOM (2011) http://www.bom.gov.au. (accessed on 2 April 2011)

Bourne GF and Tuck GA (1993) Resource Information, in R.N. Thwaites and J.M. Maher (eds.) Understanding and Managing Soils in the Central Highlands, Department of Primary Industries Training Series QE93002, Brisbane.

Brough DM, Claridge J and Grundy MJ (2004) Predicting soil attributes for regional and Sub-catchment scale modelling. ISCO 2004 -13th International Soil Conservation Organisation Conference – Brisbane July 2004

Burk L and Dalgliesh N (2008) Estimating plant available water capacity – a methodology. 40 pp. Canberra: CSIRO Sustainable Ecosystems.

Carberry P, Hockman Z, Hunt J, Dalgliesh N, McCown R, Whish J, Robertson M, Foale M, Poulton P and van Reese H (2009) Re-inventing model-based decision support with Australian dryland farmers. 3. Relevance of APSIM to commercial crops. In: Crop and pasture science, **60** (11), 1044-1056

Collins R, Buck S, Reid D and Spackman G (2006) Manipulating row spacing to improve yield reliability of grain sorghum in central Queensland. In The Regional Institute available at http://www.regional.org.au/au/asa/2006/concurrent/systems/4522_collinsr.htm

Craemer R and Barber M (2007) Building a business case for investment in soil information. Nation Land and Water Audit, National Heritage Trust, Canberra

Dalal R.C. and Mayer R.J (1986a) Long-term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland II Total organic carbon and its rate of loss from the soil. *Australian Journal of Soil Research*, **24**, 281-292

Dalal R.C. and Mayer R.J (1986b) Long-term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland V Rate of loss of total nitrogen from the soil profile and changes to carbon: nitrogen ratios. *Australian Journal of Soil Research*, **24**, 493-504

Dalal R.C. and Mayer R.J (1987) Long-term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland VII Dynamics of nitrogen mineralisation potentials and microbial biomass. *Australian Journal of Soil Research*, **25**, 461-472

Dalgliesh N and Foale M (1998) Soil matters – Monitoring soil water and nutrients in dryland farming systems. CSIRO/Agricultural Production Systems Research Unit. Technical Manuscript ISBN 0 643 06375 7

Dang Y, Harms B, Dalal R, Routley R, Kelly R and McDonald M (2004) Subsoil constraints in the grain cropping soils of Queensland. In: SuperSoil 2004: 3rd Australian New Zealand Soils Conference, 5 – 9 December 2004, University of Sydney, Australia

DEEDI (2006) Water-balance scheduling. Queensland Government, Department of Primary Industries and Fisheries - available at http://www.dpi.qld.gov.au/26_4362.htm (accessed on 24 March 2011)

DEEDI (2011) Recently granted tenures. Queensland Department of Mines and Energy - available at http://www.dme.qld.gov.au/mines/recent_tenures.cfm. (accessed on 28 February 2011)

DERM (2006) Queensland water monitoring catchment maps. Queensland Government, Department of Environment and Resource Management - available at http://www.derm.qld.gov.au/water/monitoring/ current_data/map_qld.php. (accessed on 23 March 2011)

DERM (2008) Queensland land use maps - 1999 and 2004. Queensland land use mapping project, Queensland Government, Department of Environment and Resource Management

DERM (2010a) Identifying and mapping strategic cropping land. Queensland Government, Department of Environment and Resource Management

DERM (2010b) Protecting Queensland's strategic cropping land: a policy framework. Queensland Government, Department of Environment and Resource Management

DERM (2010c) Strategic cropping land…striking the right balance. Queensland Government, Department of Environment and Resource Management

DERM (2010d) Criteria for determining strategic cropping land on-ground - draft for comment by SCL Stakeholder Advisory Committee (not Government policy). Queensland Government, Department of Environment and Resource Management, November 2010

DERM (2010e) Strategic cropping land – draft trigger map. Queensland Department of Environment and Resource Management

DERM (2011a) Queensland's strategic cropping lands criteria - field assessment and recommendations. Department of Environment and Resource Management (Confidential presentation to the Queensland Resources Council and the Queensland Farmers Federation - 21 February 2011)

DERM (2011b) Protecting Queensland's strategic cropping land. Proposed criteria for identifying strategic cropping land. Department of Environment and Resource Management.

DERM (2011c) Protecting Queensland's strategic cropping land. A technical assessment of the proposed criteria for identifying strategic cropping land. Department of Environment and Resource Management.

DERM (2011d) Strategic Cropping Land - frequently asked questions – available at http://www.derm.qld.gov.au/land/planning/strategic-cropping/index.html (accessed on 1 June 2011)

DIP (2010) Strategic cropping land policy and planning framework -discussion paper. Queensland Government, Department of Infrastructure and Planning

DME (1995) Technical guidelines for the environmental management of exploration and mining in Queensland. Queensland Department of Mines and Energy, January 1995

DPI (1990) Guidelines for agricultural land evaluation in Queensland. Queensland Government, Department of Primary Industries

DPI (2006) Cropping soils of central Queensland - available at http://www2.dpi.qld.gov.au/fieldcrops/3163.html (accessed on 20 March 2011)

FAO (1976) A framework for land evaluation. FAO Soils Bulletin 32

FAO (1983) Guidelines: land evaluation for rainfed agriculture. FAO Soils Bulletin 52

Fell J, Mackinnon D, and To H (2010) Grains: outlook for wheat, coarse grains and oilseeds to 2014-15. Australian Commodities **17**(1), ABARE

Freebairn DM, Littleboy M, Smith GD and Coughlan KL (1990) Optimising soil surface management in response to climate risk. In: Muchow RC and Bellamy JA (Eds) Climate risk in crop production: models and management for the semiarid tropics and subtropics, pp. 283-305

Gardner EA, Coughlan KJ (1982) Physical factors determining soil suitability for irrigated crop production in the Burdekin-Elliot river area. Queensland Department of Primary Industries agricultural Chemistry Technical Report No 20.

Gardner EA, Coughlan KJ and Silburn DM (1988) Soil water measurement and management on vertisols in Queensland, Australia. FAO

GRDC (2010) Farm gross margin guide. Grains Research and Development Corporation - available from http://www.grdc.com.au/uploads/documents/fgmg_2010_lowres-Part3.pdf. (accessed on 15 March 2011)

Gunn, RH (1974) Soils of the Balonne-Maranoa area. CSIRO Aust. Land Res. Ser. No.33

Hajkowicz, S (2004) Evaluating natural resource management investment performance with multi-attribute utility theory. In: Papers from An Occasional Symposium held 15 October 2004 by CSIRO Sustainable Ecosystems, a partner in the CIRM Social Dimensions of Natural Resource Management Working Group. CSIRO, 2004.

Hammer GL, van Oosterom E, McLean G, Chapman SC, Broad I, Harland P and Muchow R (2010) Adapting APSIM to model the physiology and genetics of complex adaptive traits in field crops. Journal of Experimental Botany **61**: 2185-2202

Hinchliffe S (2010) Press Release by The Honourable Stirling Hinchcliffe, Minister for Infrastructure and Planning, 10 February 2010

Jones K (2011) Press Release by The Honourable Kate Jones, Minister for Environment and Resource Management, 10 February 2010

Keating BA, Carberry P S, Hammer G L, Probert ME, Robertson MJ, Holzworth D, Huth NI, Hargreaves JNG, Meinke H, Hochman Z, McLean G, Verburg K, Snow V, Dimes JP, Silburn M, Wang E, Brown S, Bristow KL, Asseng S, Chapman S, McCown RL, Freebairn DM, and Smith CJ (2003). An overview of APSIM, a model designed for farming systems. European Journal of Agronomy **18**, 267-288

Landon JR (1984) Booker tropical soil manual. Booker Agricultural International LTD, Bloomsbury House, London

Littleboy M, Silburn DM, Freebairn DM, Woodruff DR, Hammer GL and Leslie JK (1990) Impact of soil erosion on production in cropping systems. 1. Development and validation of a simulation model. *Australian Journal of Soil Research*, **30**(5), 757-774

Liu H, Li G, Cumberland W and Wu T (2005) Testing statistical significance of the area under a receiving operating characteristics curve for repeated measures design with bootstrapping. Journal of Data Science, **3**, 257-278

MacNish SE (1987) Roma district land management field manual. Queensland Department of Primary Industries, Land Resources Branch, Training Series QE87001

Maher JM (1996) Understanding and managing soils in the Murilla, Tara and Chinchilla Shires – Field Manual. Department of Natural Resources and Mines, Land Management Manual QE96001

Marshall JP, Crothers RB, Macnish SE, and Mullins JE (1988) Land management field manual: South-east Darling Downs districts, Queensland Department of Primary Industries, QE88001

McDonald RC. (1975) Soil Survey and Land Evaluation. Queensland Department of Primary Industries, Agricultural Chemistry Technical Report No 6

McDonald RC and Isbell RF (2009) Soil profile. In 'Australian soil and land survey field handbook (3rd edn).' (National Committee on Soil and Terrain) (CSIRO Publishing: Melbourne)

McKenzie N, Gallant J and Gregory L (2003) Estimating water storage in soils at catchment scales. Cooperative Research Centre for Catchment Hydrology. Technical Report 03/03

McKenzie N and Cresswell H (2002) Estimating soil physical properties using more readily available data: In 'Soil physical measurement and interpretation for land evaluation'.(CSIRO Publishing: Melbourne)

McKenzie N and Grundy M (2008) Approaches to land resource survey: In 'Guidelines for surveying soil and land resources (2nd edition)' (Eds McKenzie NJ, Grundy MJ, Webster R, Ringrose-Voase AJ), pp. 15-25 (CSIRO, Melbourne)

McKenzie N, Grundy M, Webster R and Ringrose-Voase A (2008) 'Guidelines for surveying soil and land resources (2nd edition)'. (CSIRO Melbourne)

Meinke H, Rabbinge R, Hammer GL, van Keulen H and Jamieson PD (1997) Improving wheat simulation capabilities in Australia from a cropping systems perspective II - Testing simulation capabilities of wheat growth. *European Journal of Agronomy* **8**, 83-99

Moore D, Hall D and Russell J (1998) Soil water. In: "Soilguide: A handbook for understanding and managing agricultural soils." (Ed. G Moore). Agriculture Western Australia, Bulletin No.4343, South Perth, Western Australia

Mullins JA (1981) Estimation of the plant available water capacity of a soil profile. *Australian Journal of Soil Research*, **19**, 197-207

Northcote KH (1979) A factual key for the recognition of Australian soils, Rellim Technical Publishing, Adelaide

Pacific Seeds (2008) Trials 2008 - Western Downs and Maranoa. Pacific Seeds

Perry, RE (1968) Lands of the Dawson-Fitzroy area, Queensland. Land Research Series No. 21, CSIRO Aust.

Peverill KI, Sparrow LA and Reuter DJ (1999) Soil Analysis: an interpretation manual, CSIRO publishing

Potgieter AB, Hammer GL and Butler D (2002) Spatial and temporal patterns in Australian wheat yield and their relationship with ENSO. Australian Journal of Agricultural Research, **53**, 77-89

QRC (2010) Feature: strategic cropping land. In 'State of the Sector', September quarter 2010. Queensland Resources Council

Ringrose-Voase AJ (2008) Quantitative land evaluation. In 'Guidelines for surveying soil and land resources'. (Eds McKenzie NJ, Grundy MJ, Webster R, Ringrose-Voase AJ) pp. 451-468 (CSIRO Publishing: Melbourne)

Robertson S (2010) Press Release by The Honourable Stephen Robertson, Minister for Natural Resources, 23 August 2010

Rowland T, O'Donnell T, Weller D and Witte C (2002) Catchment scale land use mapping in Queensland. In: 'Proceedings of the 11th Australasian Remote Sensing and Photogrammetry Conference', September 2-6, Brisbane, Queensland

Russell JS (1984) Management of cracking clay soils in rainfed environments. In: 'The properties and utilisation of cracking clay soils. Symposium proceedings' (Eds McGarity JW, Hoult EH and So HB), The University of New England, Australia, 24-28 August 1984. *Reviews in Rural Science* **5**, 317-325

Shaw RJ and Yule DF (1978) The assessment of soils for irrigation, Emerald, Queensland. Queensland Department of Primary Industries Agricultural Chemistry Technical Report No 13.

Shaw R (2011) Review Report. Protecting Queensland's strategic cropping land: An independent expert review of the criteria for identifying strategic cropping land. Report for the Department of Environment and Resource Management, Brisbane.

Spackman G, McKosket, K, Farquharson A, and Conway M. (2001) Innovative management of grain sorghum in Queensland. In The Regional Institute available at http://www.regional.org/au/asa/2001/1/a/spackman.thm

Thomas EC, Gardner EA, Littleboy M and Shields P (1995) The cropping systems model PERFECT as a quantitative tool in land evaluation: An example for wheat cropping in the Maranoa area of Queensland. *Australian Journal of Soil Research* **33**, 535-554

Thwaits RN and Macnish SE (1991) Land management manual - Waggamba Shire. Queensland Department of Primary Industries and Waggamba Conservation Committee, Queensland Department of Primary Industries, Training Series QE90014

Vandersee BE (1975) Land inventory and technical guide: Eastern Downs Area Queensland – land classification and landuse. Queensland Department of Primary Industries, Division of Land Utilisation Technical Bulletin no 7

Wang E, Xu J, Jiang Q, Austin J (2009) Assessing the spatial impact of climate on wheat productivity and the potential value of climate forecasts at a regional level. *Theoretical and Applied Climatology,* **95**:311-330

Whish J, Butler G, Castor M, Cawthray S, Broad I, Carberry P, Hammer G, McLean G, Routley R, and Yeates S (2005) Modelling the effects of row configuration on sorhum yield reliability in north-eastern Australia. *Australian Journal of Agricultural Research*, **56**, 11-23

Williams J, Prebble RE, Williams WT and Hignett CT (1983) The influence of texture, structure and clay mineralogy on the soil moisture characteristic. *Australian Journal of Soil Research*, **21**, 15-32

Wylie P (2008) Managing sorghum for high yields, Grains Research and Development Corporation

Appendix A

Generic thresholds for land suitability for rain-fed broadacre cropping in Queensland
(Source: DME 1995) (bold font in table text indicates cross-reference to the eight criteria by DERM (2011b)

Criteria	Threshold limit				
	Class 1	Class 2	Class 3	Class 4	Class 5
Slope	Slopes <0.5% on cracking clays without melonholes, or Slopes <1% on melonhole clays, or Slopes <1% on non-sodic rigid soils, or Slopes <0.5% on sodic rigid soils	Slopes 0.5-1% on cracking clays without melonholes, or **Slopes 1-3% on melonhole clays**, or Slopes 1-2% on non-sodic rigid soils, or Slopes 0.5-1% on sodic rigid soils	**Slopes 1-3% on cracking clays without melonholes, or Slopes 2-4% on non-sodic rigid soils**, or Slopes 1-2% on sodic rigid soils	**Slopes 3-5% on cracking clays without melonholes, or Slopes 4-6% on non-sodic rigid soils, or Slopes 2-3% on sodic rigid soils**	Slopes >5% on cracking clays without melonholes, or Slopes >6% on non-sodic rigid soils, or Slopes >3% on sodic rigid soils
Rockiness	<10% coarse surface gravel (>6 cm diam) and rock outcrop	10-20% coarse surface gravel and rock outcrop	**20-50% coarse surface cobble (6-20 cm diam) and rock outcrop**	50-90% coarse surface cobble and rock outcrop, or 20-50% stone and boulders (>20 cm diam)	>90% coarse surface cobble and rock outcrop, or >50% stone and boulders (>20 cm diam)
Microrelief	No melonholes	Melonholes 30-60 cm deep cover <20% surface area, or Melonholes >60 cm deep cover <10% surface area	**Melonholes 30-60 cm deep cover 20-50% surface area**, or Melonholes >60 cm deep cover 10-20% surface area	Melonholes 60-100 cm deep cover 50% surface area	Melonholes at least 100 cm deep cover 50% surface area
Soil depth	n/a	n/a	n/a	n/a	n/a
Wetness	Undulating terrain or elevated plains	Low lying level plains with melonholes covering <25% surface area, or Rigid soils with sodic subsoil (ESP 6-14) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 75 cm of the surface	Low lying level plains with melonholes covering 25-50% surface area, or Rigid soils with sodic subsoil (ESP ≥15) within 60 cm of the surface, or Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Seasonal swamps and low lying run-on areas	Permanent swamps and lakes
Soil acidity			**pH <5 60-90 cm below surface pH>9 60-90 cm below surface**	pH <5 30-60 cm below surface pH>9 30-60 cm below surface	pH <5 within 30 cm od surface pH>9 within 30 cm of surface
Salinity	Rootzone EC <0.15mS/cm or Rootzone Cl <300 ppm	Rootzone EC 0.15 – 0.3mS/cm or Rootzone Cl 300-600 ppm	Rootzone EC 0.3 – 0.9mS/cm or **Rootzone Cl 600-900 ppm**	Rootzone EC 0.9 – 1.2mS/cm or Rootzone Cl 900-1500 ppm	Rootzone EC >1.2mS/cm or Rootzone Cl >1500 ppm
Soil water storage	PAWC >150mm	PAWC 125-150mm	**PAWC 100-125mm**	PAWC 75-100mm	PAWC <75mm

Appendix B

Planting rules used for APSIM simulations for wheat and sorghum.

Planting Rule	Wheat	Sorghum
Planting window	15 May - 10 July	15 October - 10 January
Must sow?	Yes	Yes
Amount of rain (mm)	25	30
No of rain days	7	3
Minimum PAW	100	100
Sowing density (plants per m^2)	100	7
Sowing depth (mm)	30	30
Cultivar/variety	Hartog	'early'
Row spacing (mm)	250	1000
Skip row	N/A	Solid
Fertiliser	80 kg ha^{-1} NO_3-N	150 kg ha^{-1} urea_N

Appendix C

Soil profiles selected to simulate crop yields for the predominant soil of a district

Location	Land Resource Study	Soil Type selected[2]	PAWC[1] (mm)	APSIM profile no
Charleville	N/A	Cracking clay	119	063
Mitchell	Gunn (1974)	Cracking clay	119	063
Roma	Macnish (1987)	Wondolin	132	040
Miles	Maher (1996)	Arden	119	063
Chinchilla	Maher (1996), Marshall et al. (1988)	Arden	119	063
Dalby	Vandersee (1975) Marshall et al. (1988)	Mywybilla	250	001
Pittsworth	Marshall et al. (1988)	Vertosol3	136	011
Barcaldine	N/A	Capella	145	049
Emerald	Bourne and Tuck (1993)	Capella	145	049
Blackwater	Bourne and Tuck (1993)	Capella	145	049
Rockhampton	Perry (1968)	Capella	145	049
Goondiwindi	Thwaits and Macnish (1991)	Kalagen	187	220
Taroom	Macnish (1993)	Wandoan	132	112
Clermont	Bourne and Tuck (1993)	Capella	145	049

1 PAWC generally selected to match that described for the predominant soil. 2 Soil profile used to match predominant vertosol in district.

Attachment 2

ASSSI
Australian Society of Soil Science Inc

21st July 2011

The Director
Land Management
Department of Environment and Resource Management
GPO Box 2454
Brisbane QLD 4001

Dear Sir/Madam

QUEENSLAND BRANCH OF AUSTRALIAN SOCIETY OF SOIL SCIENCE INC SUBMISSION ON *PROTECTING QUEENSLAND'S STRATEGIC CROPPING LAND PROPOSED CRITERIA FOR IDENTIFYING STRATEGIC CROPPING LAND* PUBLICATION

Further to the Queensland Branch of the Australian Society of Soil Science Inc (ASSSI) submission of 8 March 2010 to the Queensland Department of Infrastructure and Planning on the Government's *Strategic Cropping Land Policy and Planning Framework Discussion Paper*, ASSSI Queensland Branch wishes to reaffirm its strong support for action by the Queensland Government to ensure future food security by protecting the most productive cropping lands from alienation. However, ASSSI is greatly concerned with the adequacy of the existing documentation on Strategic Cropping Land (SCL), how this might be incorporated into the proposed subsequent State Planning Policy and legislation and how it may be implemented.

While impacts due to mining on food and fibre production are one area of concern to ASSSI, this submission addresses all forms of land use that may limit the long term use of the most productive land for food and fibre production.

Nature of ASSSI

As indicated in its previous Submission, the Queensland Branch is the Queensland component of the Australian Society of Soil Science Inc. (ASSSI). ASSSI is a not-for-profit organisation that serves as the peak body for in excess of 1000 scientists across Australia. The Society seeks to advance soil science in professional, academic, and technical fields. Members are drawn from all States and Territories of Australia and work in government departments, research organisations, universities and private enterprise. All ASSSI members are also members of the International Union of Soil Science (IUSS) which is made up of 65 national societies representing approximately 40 000 soil scientists from around the world.

Australian Society of Soil Science Inc Federal Office:
PO Box 1349 WARRAGUL Victoria 3820
Ph: +61 3 5622 0804 Fx: +61 3 5622 0806 Email: office@asssi.asn.au Web: www.asssi.asn.au

The ASSSI is able to draw on expertise in the following competency areas in preparing this submission:

- Soil attributes in terms of their physical and chemical properties. This knowledge improves the understanding of a soil's capacity and resilience.
- The identification and management of soil constraints. This knowledge informs decisions on land use determination and management responses.
- Soil survey and the determination of land suitability for a range of rural and non rural uses. This expertise provides objective assessment of land attributes and informs the selection of appropriate and sustainable land uses that avoid degrading the natural resource condition of the site and/or its surrounds.
- Land use planning and management. This knowledge informs the planning process so that the selected range of land use options will not degrade the resource base.
- Knowledge of rehabilitation capacities of soils after use. This knowledge informs the management of soils post the proposed land use change and is especially useful if the original land use determination is adequately informed.

ASSSI Submission

In making this submission, the ASSSI has drawn on a number of studies members have participated in, or have knowledge of, including land management manuals that apply to areas nominated as 'Zones of Strategic Cropping Land' and a 1981 report prepared by Weston et al titled "Assessment of the Agricultural and Pastoral Potential of Queensland".*

Objectives of this submission

The Queensland Branch of ASSSI wishes to re-emphasise three key issues to the Queensland Government. These are:

- There are many areas of highly productive soils throughout Queensland which have attributes that provide the State with a competitive advantage for food and fibre production.
- These soils are scarce in areas with a favourable rainfall or access to irrigation supplies from surface waters or an underground water regime.
- The potential impacts from permanent alienation or severely reduced productivity after rehabilitation of these soils (such as after some methods of mining) in terms of productive capacity are substantial.

Australian Society of Soil Science Inc Federal Office:
PO Box 1349 WARRAGUL Victoria 3820
Ph: +61 3 5622 0804 Fx: +61 3 5622 0806 Email: office@asssi.asn.au Web: www.asssi.asn.au

This submission is not 'anti' or 'pro' any particular land use, it aims to seek the protection of the scarce arable land suited for food and fibre production and acknowledges that food security will become an increasingly important issue in the near future as world stocks reach disturbingly low levels while recognising the valuable contribution of mining (be it short-term) to Australia's economy.

A possible way forward

While ASSSI applauds the Government's initiative to address this issue so that the benefits of various types of development can be enjoyed by the community while protecting agricultural productivity, it is dismayed at:

- the creation of yet new criteria to identify the most productive cropping land;
- the onus being placed on the landholder (or the company wishing to undertake a particular development) to use the proposed criteria to identify SCL when maps have already been produced, for good quality agricultural land (GQAL in many instances but not all mirrors the SCL indicative mapping) under the Queensland Government's *State Planning Policy 1/92, Development and Conservation of Agricultural Land*;
- the confusion that is likely to exist when making the assessments due to critical errors of fact in Table 3 on water holding capacity in *Protecting Queensland's strategic cropping land – Proposed criteria for identifying strategic cropping land.*

ASSSI is also concerned, because of the need for scientific interpretation of the criteria that any assessment is initially undertaken and subsequently reviewed by a competent person accredited by an appropriate professional body. In addition, validation of the assessment within the government agency responsible for decision making should be undertaken by a competent person accredited by an appropriate professional body.

While in part addressed in the documentation ASSSI is still concerned at the reference to "strategic cropping land" as this implies that it is an outcome of a planning process which includes the consideration of other factors such as access to irrigation water. Further, ASSSI is concerned at the lack of a clear and transparent framework when further determinations are needed to be made on the use or management of SCL when competing and potentially incompatible uses are involved.

ASSSI believes that all lands currently mapped as GQAL should be deemed to be SCL be used as trigger maps (effectively those lands deemed to be SCL until an assessment has been made to determine otherwise using the proposed criteria) but with the data for water holding capacity amended to reflect the actual situation.

Because of the urgency to resolve this issue (so as to provide greater certainty for the rural, development, and mining industries), ASSSI would be concerned if its comments delayed resolution of this strategic issue. Accordingly, ASSSI is prepared to assist the Government in moving forward.

Please do not hesitate to contact me via email or phone if you would like to discuss our submission further. My contact details follow:

Yours faithfully

Dr Silvana Santomartino
Secretary

And on behalf of
Dr Louise Cartwright
President Queensland Branch
Australian Society of Soil Science Inc
lcartwright@eesi.biz

* "Assessment of the agricultural and pastoral potential of Queensland" by EJ Weston, J Harbison, JK Leslie, KM Rosenthal and RJ Mayer", Agriculture Branch Technical Report No. 29 , Queensland DPI, Brisbane (1981).

SUBMISSION
from the Queensland Branch of the Australian Society for Soil Science Inc.

Reference is again made to the main comments made in the previous ASSSI Submission and the Queensland Government's response to those comments.

Issue 1: Scope of 'Strategic Cropping Land' Policy

While the Queensland Government announced its policy position as:

The government considers that the best cropping land, defined as strategic cropping land, is a finite resource that must be conserved and managed for the longer term. As a general aim, planning and approval powers should be used to protect such land from those developments that lead to its permanent alienation or diminished productivity. Regrettably, the statement that "best cropping land, defined as strategic cropping land, is a finite resource that **must** be conserved and managed for the longer term" is inconsistent with the wording of policy principles which appear to be discretionary. Also will SCL be binding on the Crown in terms of community works? If not there need to be clear guidelines on what constitutes exceptional circumstances

If the intent of the policy is limited to managing conflicts between agricultural and mining uses, the ASSSI is of the view that the processes employed need to be consistent with other development processes both in a statutory planning and development assessment context. In both scenarios, many elements of the current State Planning Policy 1/92 (SPP1/92) are still relevant, but the will to implement needs to be more strongly supported especially as the original discussion paper stated that the new planning instrument will 'subsume' SPP1/92.

Issue 2: The adequacy of the proposed criteria for defining 'strategic cropping land'

Many of the criteria:

- Overlap.
- Focus on soil and landscape features.
- Require interpretation and thus would require assessment by a competently trained person.
- Fail to provide a basis for decision-making where there are conflicts between agricultural and other competing uses.

It is disappointing that water holding capacity, possibly the most relevant of the criteria and the most difficult to assess, is in part to be estimated from texture classes which, because they grossly underestimate water holding capacity for some heavy clay soils, will lead, if adopted, to the exclusion of much of the productive lands from the SCL protection area and thus more accessible to alienation.

Issue 3: Decision framework for deciding which cropping land should be mined

The general community had an expectation that good quality agricultural land (GQAL) as defined in SPP1/92 would be identified and protected, through planning, based on a consideration of all of the relevant criteria, e.g. land in terms of soil, landscape, location, water availability, infrastructure, legal and other factors. However, GQAL focused on limited soil and site characteristics. There was a general expectation that SCL would take a more inclusive approach. Unfortunately it does not. It is left to strategic and statutory planners to make such determinations on the preferred use of land without guidance on how the competing issues might be resolved and how the other factors that determine preferred land use, such as availability of irrigation water and cropping versatility which ultimately impact on crop frequency, risk and economics, might be utilised.

Implicit in the generic definitions of the 'criteria' is the recognition that agricultural uses on 'Strategic Cropping Land' have the ability to produce food and fibre in perpetuity. Urban development usually produces benefits in perpetuity, the expectation, not always realised, is that industrial development will produce benefits in perpetuity but mining is a relatively short term venture. It is essential that if it is decided that a non agricultural development venture begin, developers provide adequate mitigation measures or, in the case of mining, need to be able to demonstrate that the areas can be restored to original productivity for cropping afterwards. In this regard the concept of 'make good' for any damage to land or waters is in many cases not physically possible.

Regrettably, the supporting guidelines only document the processes needed to implement the policy at the development assessment phase. Stronger more definitive statements are needed to firmly inform the strategic planning elements of the process. Clearer and more detailed articulation of these is needed to avoid the difficulties that occurred with the implementation of SPP1/92. We assume that significant elements of SPP1/92 will continue to exist as it is not clear if this Strategic Cropping Land Policy will 'subsume' all elements that are currently in place with SPP1/92. The relationship with SPP1/92 needs to be clearly enunciated and the planning principles supporting that policy need to be considered relevant to this policy.

The strategic planning content for this wider discussion is built around economic diversity and risk management across rural and regional Queensland for the longer term. The processes for assessing development are in part well defined in SPP1/92 guidelines.

Australian Society of Soil Science Inc Federal Office:
PO Box 1349 WARRAGUL Victoria 3820
Ph: +61 3 5622 0804 Fx: +61 3 5622 0806 Email: office@asssi.asn.au Web: www.asssi.asn.au

The ASSSI sees merit in the policy being supported by other related principles. These principles need to be inclusive and cover policy positions for the:

- Protection of strategic cropping land for food and fibre production purposes.
- Protection of all strategic land and water assets essential for crop production.
- Regional assessment of natural resources and impacts of development
- Landscape function and biodiversity conservation
- Development of a clear and data supported 'overwhelming' public interest test so that it is a component of any assessment of a land use change.

Issue 4: Legislative amendments to protect strategic cropping land

As there is currently no information on whether there will be amendments to statutes other than the *Sustainable Planning Act (2009),* it is not clear as to the Government's intention in this regard. While SPP1/92 seeks to protect cropping land from inappropriate development, mining development is exempt from regulation under that Act. The ASSSI is of the view that this exemption needs to be removed and appropriate amendments made to the relevant legislation such as the *State Development and Public Works Organisation Act 1971; Mineral Resources Act 1992*; *Petroleum and Gas (Production and Safety) Act 2004*, the *Petroleum Act 1923* and *Environment Protection Act 1994*) so that Strategic Cropping Land is recognised in those Acts, and ensures that the levels of investigation required in the legislation are consistent and that there be a thorough consideration given to assessing off-site and cumulative environmental risk associated with project assessment.

The ASSSI is of the view that legislation should be amended to require the Government, prior to making a grant of tenure and issuing of environmental authorities and compensation, to be subject to a publicly accessible planning process which undertakes an assessment of the costs and benefits of the alternative land uses and the externalities of any future development. The granting of exploration rights, leading to the commitment of funds by those receiving those grants, creates a not unreasonable expectation that, provided an appropriate impact assessment has been carried out with impacts identified that can be adequately addressed, a future right exists to exploit the natural resources.

The footprint of petroleum and gas activities in terms of severity of disturbance is significantly smaller than for open cut mining activities. However, the impact in terms of extent of disturbance and fragmenting/ alienating cropping lands is real. Drillers need ongoing access, and this often requires road construction across fields. These activities result in the curtailing of many farm management activities such as precision agriculture and timing of aerial spraying operations,

Australian Society of Soil Science Inc Federal Office:
PO Box 1349 WARRAGUL Victoria 3820
Ph: +61 3 5622 0804 Fx: +61 3 5622 0806 Email: office@asssi.asn.au Web: www.asssi.asn.au

compaction around impact zones or drill areas and a higher risk of erosion. In addition, the cumulative effects of petroleum and gas activities need to be considered for their effects on a regional and state wide scale. For example the effects on the Murray Darling Basin and the Great Artesian Basin need to be assessed. Associated issues such as surface and groundwater flow systems, salinity, drainage of aquifers and effects on catchments will be requiring further investigation. On this basis, these activities should be treated in a similar fashion in terms of process for determining SCL and how land can be used. The importance of the issues to be investigated may differ with location and land use, but all need to be integrated into the planning process.

Issue 5: Assessment of mining developments on all productive cropping land

In the short-term it is suggested that all good quality agricultural lands should be subject to assessment with those defined as being within protected areas being excluded from alienation unless it can be reasonably demonstrated, in the case of mining, that the land can be returned to cropping in the longer term at a similar level of cropping certainty to that which exists prior to mining. It is in circumstances where mining is a preferred land use or it can be demonstrated that mining and cropping can coexist, that mining proposals would need to be rigorously assessed.

While little information was provided in the original discussion paper that permitted informed input on the guidelines, ASSSI is of the view that the guidelines need to:

- Detail analysis and investigation standards needed to demonstrate an understanding of land and water attributes, their relationships with competing land uses and wider landscape functions. This information is needed to determine potential impacts resulting from any proposed development (e.g. more intensive farming, urban, industrial, mining, forestry for carbon sequestration purposes) on-site, off-site and cumulatively within a local district. Guidelines set out for SPP1/92 appear to be adequate here.
- Inform decision makers of potential conflicts in land use on the same parcel of land on adjoining or nearby parcels of land.
- Inform on requirements for determining "overwhelming public interest" in order to remove undue restrictions on decisions by the Court.
- Inform conflict resolution processes through the provision of useful information and data. The guidelines should outline a decision-making framework needed to objectively decide on the preferred fate of a particular area.

Guidelines serve a cyclic role of informing the strategic planning process and detailing assessment processes for all development applications. On this basis, guidelines for the development of strategic cropping lands should be similar across legislation, regardless of the development use.

Australian Society of Soil Science Inc Federal Office:
PO Box 1349 WARRAGUL Victoria 3820
Ph: +61 3 5622 0804 Fx: +61 3 5622 0806 Email: office@asssi.asn.au Web: www.asssi.asn.au