QUEENSLAND resources COUNCIL

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4 November 2011

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

via email: earec@parliament.qld.gov.au

Dear Mr Hansen

Thank you for the opportunity to provide a submission to the Environment, Agriculture, Resources and Energy Committee's inquiry into the *Strategic Cropping Land Bill 2011*.

As you know, the Queensland Resources Council (QRC) is the peak representative organisation of the Queensland minerals and energy sector. The QRC's membership encompasses exploration, production, and processing companies, energy production and associated service companies. The QRC works on behalf of members to ensure Queensland's resources are developed profitably and competitively, in a socially and environmentally sustainable way.

Throughout the development of the strategic cropping land policy, QRC has recognised that preserving Queensland's best cropping land is a valid issue for government policy and the focus of our contribution to the public debate has been to try to assist with accurate data and expert opinion, to achieve well-informed, fair and transparent outcomes. Consequently, we are concerned that, after all this work, the Bill itself has ultimately been rushed to the extent that there are a multitude of errors, it does not take into account important developments in soil science and there are numerous issues affecting rights and liberties under the *Legislative Standards Act 1992*, without any sound justification which could in any way be linked to the State's interest in the best cropping land.

QRC members have taken a keen interest in the development of the strategic cropping land policy and the QRC Secretariat has been an active member of the Department of Environment and Resource Management (DERM) Stakeholder Advisory Committee. Key aspects of QRC's contribution to the public debate have included:

- → Surveying QRC members to gain an accurate picture of how many resource projects were covered by the strategic cropping land trigger maps and how much investment had already been made in these tenures;
- → Seeking expert legal opinion on the best legislative format for implementing the strategic cropping land policy. This advice suggested the semi-standalone Act for strategic cropping land, which the Government has adopted;

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- → Initiating a series of workshops with DERM's soil scientists and other key stakeholders to look at how to best develop a meaningful trigger map and how to represent the Government's policy intentions spatially by considering the relationship of possible criteria to cropping productivity;
- → Being hosted by *Future Food Queensland* to visit farms and to meet with farmers in Queensland's two key cropping areas – the Darling Downs and the Golden Triangle - which have turned out to be in the strategic cropping land protection zones;
- → Commissioning a scientific review (attached) of the proposed strategic cropping land criteria which have been used to identify strategic cropping land in the field and conducting an open workshop of soil scientists to discuss the report which identified a number of shortcomings in the proposed criteria; and
- → Working with QRC members to develop a practical set of transitional measures, which would recognise the long lead times for developing resource projects. These QRC proposals were adopted in part as the basis of the transition mechanisms that the Government subsequently announced on 23 May 2011.

It is also worth drawing to the Committee's attention that the development of this policy has been a complex and contentious issue. Not only has the issue been constantly in the media, often presented in lamentably emotive terms, but also the administrative responsibility for the policy has been in a state of flux. During the development of the policy, strategic cropping land has been the responsibility of three different departments and four different Ministers. As you would expect, these changes have posed a challenge for Departments to maintain the continuity of officials to work on the development of this policy.

Unfortunately, as a result, the preparation of this *Strategic Cropping Land Bill 2011* has been rushed. This rush has generated numerous major changes in policy reflected in the Bill, which are inconsistent with the Government's previous announcements, the policy reasoning explained at the discussion paper stage and the information which has been published in factsheets on the DERM website.

Industry has relied on the various policy announcements and factsheets in making investment decisions for more than a year now. Provisions introducing an element of retrospectivity to the commencement of some obligations were also based on a reasonable expectation that the Bill would be consistent with the policy announcements with which the retrospective commencement has been linked, and that has turned out not to be the case, for the reasons which will be explained in more detail in this submission. Consequently, any possible justification which could otherwise have been argued for the elements of retrospectivity is now outweighed by the fact that the Bill is inconsistent with legitimate expectations based on policy announcements (Section 4(2)(g) *Legislative Standards Act* 1992).

In addition, QRC is concerned that the Bill will have a greater impact on existing, established operations (as opposed to future development) than was previously disclosed in policy announcements or published factsheets on the DERM website. See for example the references in DERM's webpage for resource developers which talks about "new projects" and "proposed development", which is also the language, used in the flowchart for development proponents.

By way of example:

- → even if the project does not currently fall within potential strategic cropping land as identified on trigger maps or protection areas, these maps could be amended in future by regulation (S34 and 35);
- → if the project does fall within potential SCL on a trigger map:
  - the application of the cropping test on a whole of property basis, using the land tenure boundaries, could mean that land that has been within the surface area of a mining lease and not cropped at all during the whole of the relevant 12 year test period could *still* satisfy the cropping test, because another part of the underlying land tenure was cropped (S45);
  - any activities within the existing mining lease area requiring any renewal, variation or amendment to existing authorities or approvals would trigger application of the Act, due to the very narrow transitional arrangements (S22).

Such an outcome would appear to go much further than the stated policy objectives of protecting current cropping land, and in effect gives the legislation a highly retrospective effect. The policy and planning framework for strategic cropping land says:

> *"The new policy framework gives effect to the government's commitment to protect Queensland's best cropping land and strikes a balance between competing interests as Queensland grows. The legislation will ensure that <u>proposed development</u> [emphasis added] that may impact on Queensland's best cropping land is assessed to ensure it does not cause permanent damage to this valuable resource."* February 2010, online reference.

Errors in key deadlines

The one error of which the Department (DERM) has made QRC aware is in S281(1)(b), the transitional provisions. The draft Bill sets a deadline for applications of 23 August 2010, whereas the fact sheets describing the transition mechanism released in May 2011 set the deadline as 23 August 2012. DERM have assured QRC that this section will be subject to amendments to be moved in Committee by the Minister for Natural Resources, the Hon Rachel Nolan MP.

However, QRC is concerned that the same erroneous deadline of 23 August 2010 appears to have been applied in section 279(b)(i) in relation to the certificate of application. Once again, QRC would hope that this section would be amended to be consistent with S281(1)(b) so that the Bill aligns with the Government's May 2011 fact sheets on transitional mechanisms.

Drafting errors arising from undue haste

Despite the complexity of the Bill and the fact that no similar legislation exists in any Australian jurisdiction, the preparation of the *Strategic Cropping Land Bill 2011* has been rushed. As a result, there has been no chance for stakeholders to review and comment on the drafting. In addition to the typographical errors noted for S279 and S281, QRC members have identified a number of concerns:

- → The date of assent is set for 30 January 2012, which provides almost no time for the development of key regulations and other necessary elements to underpin the introduction of the Act.
- → As a result, many of the elements which would ordinarily be enacted through regulation have been drafted as black letter legislation. Enshrining the proposed scientific criteria (schedule 1) used to identify strategic cropping land, before they have been properly field-tested, is an example of where the haste to enact the legislation is likely to create difficulties when the criteria need to be refined in the future.

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- → The timeframe to provide this submission to the Committee is also very short, given the length, complexity and significance of the legislation. There does not appear to be any sensible justification for rushing through a Bill which is riddled with errors and inconsistencies. This is not a Bill to deal with a natural disaster, terrorism or some kind of similar emergency. Given the undue haste, QRC cannot be sure that we have identified every error in the Bill. If we had more time, we would have been able to undertake a more thorough review in more detailed consultation with our members.

The attachment to this Submission sets out detailed concerns with individual sections. However, we have summarised these concerns below, grouped in accordance with a set of key issues: -

Consideration of scientific arguments

This policy foundation for this Bill was supposed to have been about protecting Queensland's best cropping land, which is obviously fundamentally linked to agricultural science and particularly soil science. The relationship with development impacts also ought to be soundly based on the current science relating to those impacts, but that has simply not happened. QRC acknowledges the effort that has gone into this work by government scientists, but ultimately, outcomes in relation to both protection of the best cropping land and assumptions about development impacts have been undermined by the rush to table the Bill and by policy inconsistencies.

- → Definitions of cropping history do not reflect existing agronomic practices in the five SCL cropping zones and as such do not provide an effective filter. The drafting of key tests of cropping history have been watered down to the point of irrelevance, largely because:
    - S45 seems to require that cropping history tests apply to a full property even though potentially only one or more sub-parcels may in fact be SCL (which may not have been cropped); and
    - the cropping test only requires 3 years of cropping on one of those sub-parcels in a 12 year period, for the *whole property* to satisfy the cropping test.
- → Open cut mining is axiomatically defined as causing permanent alienation with no avenue for making a case for new techniques for either mining or rehabilitation (S14).
- → Geothermal energy generation is defined as not renewable (S285), which would seem to contradict the Government's 2008 Renewable Energy Plan which says on page eight, "*emerging technologies with strategic significance for the state such as geothermal and large-scale solar thermal could receive support and be deployed on a significant scale beyond 2015.*" online reference
- → Definitions of alternative resources in the exceptional circumstances test do not reflect the reality of resource markets. It flies in the face of reality to dictate in legislation that a genuine alternative site can disregard the "*classification, grade or quality of the resource; example - if the relevant resource is coal, it does not matter whether the coal on the possible alternative site is thermal or coking*" S127(2)(d).

Consistency with existing legislation

The interactions of the *Strategic Cropping Land Bill 2011* with existing resource legislation is complex and there are a number of areas where the drafting of this Bill could have been better informed by a deeper operational understanding of the corresponding resource legislation.

- → the ability of projects that have applied for, but do not hold tenure, to access the land for the purposes of conducting an SCL assessment seems not to have been considered. Under the current land access laws, an applicant has no rights until a form of tenure is granted, yet parts of this Bill anticipates tenure applicants conducting SCL assessments (S41) prior to this grant.

- → The definition of tenure holder (S281) in the transition provisions will be very important as it is common to hold tenure through joint venture and other collective arrangements. The test as drafted does not envisage tenure being held within different company groups with a common ownership. QRC suggests that the test should be that the tenement application being held by the holder of the adjoining mining lease (ML), or "*…held by a related body corporate(s) (within the meaning of the Corporations Act) of the holder of one of the holders*."
- → The definition of the source authority for a resource project as either the underlying tenure or the environmental authority (S20) allows any SCL conditions to be applied to either the tenure or the environmental authority regardless of what change (s22) triggered the SCL assessment. The usual operation of resource legislation is to condition the authority (as a way of managing which activities can occur) rather than the tenure. It will serve to heighten perceptions of sovereign risk if SCL conditions are seen as threatening the property right embodied in the tenure.
- → Finally, the transition provisions don't recognise the Government's 2008 decision on oil shale and QER's McFarlane tenure. Part 7AAB of the Mineral Resources Act imposed a moratorium on development of QER's McFarlane tenements. Section 318ELAD provides that during the moratorium a mining tenement cannot be granted, but otherwise the status quo of the tenements are preserved. QRC suggest that the Bill amend the Mineral Resources Act to specifically include SCL in the status quo provisions of Part 7AAB.

Unnecessary and unjustified impacts on resource projects

Examples of sections of the Bill will have the effect of imposing the maximum cost, uncertainty and impact on resource projects, without any obvious benefits in terms of protecting cropping land include:

- → exemptions for existing projects and tenures only survive until the project applies for a renewal, amendment or re-grant of any part of the tenure or environmental authority – this results in a very narrow, short-term grandfathering, and effectively puts existing long-established operations and projects at risk (s22). The SCL policy was intended to apply to new (development) projects, whereas the drafting of this section will create retrospective risks for existing projects on granted production tenures;

  > *"As of today, resource development projects, such as mining, that are not well advanced in the approvals process will be subject to the full effect of the legislation to be introduced later this year",* The Hon. Kate Jones, Minister for Environment and Resource Management, 31 May 2011 online reference.

- → inconsistent treatment of infrastructure projects which are exempt from consideration – e.g. a road or a powerline to a resource project may be exempted but significant linear infrastructure (even an Infrastructure Facility of Significance (IFS) and Significant Project), such as a water pipeline, or a railway is not exempt (S6);
- → new cropping zones and protection areas can be amended and added by regulation – this raises the spectre of future waves of sterilisation of resource projects as new protection zones are announced (S34 & 45);
- → the Act gives regulators the power to apply whatever additional criteria they see fit in assessing and conditioning proposals that may impact on SCL, including, for example, using the precautionary principle and potential cumulative impacts, to constrain resource projects (S14);

- → a perplexing process whereby if land is found not to be SCL, then mitigation payments are still required to be made (S274); and
- → regulators will be required to make decisions over large areas of Queensland on the basis that Strategic Cropping land (SCL) takes precedent over **all** development interests (S11).

Given the very limited time (a calendar week) to prepare submissions, QRC is aware that many resource companies who have intense concerns about the Bill may not be in a position to make public submissions to the Committee, as relevant senior management deal with other urgent issues. A thin field of submissions should not be misconstrued as reflecting a lack of interest from the resource industry. Indeed, many companies have provided input into QRC's submission in lieu of providing their own submissions.

If the Committee is interested in hearing more information about the impact on the resources sector, QRC would be pleased to arrange a briefing with members or an opportunity to appear before the Committee.

Thank you again for the opportunity to comment on the *Strategic Cropping Land Bill 2011*. If you have any questions about any of the issues raised in this submission, or would like any further information, please feel free to contact QRC's Andrew Barger on 07 3316 2502 or andrewb@qrc.org.au

Yours sincerely

Michael Roche

Michael Roche
Chief Executive

ENCLOSED:

- → **Attachment 1:** QRC's comments on specific sections of the *Strategic Cropping Land Bill 2011*
- → **Attachment 2:** The scientific review of the proposed strategic cropping land criteria commissioned by QRC.

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Strategic Cropping Land Bill 2011

Specific comments on individual sections

Chapter One - Preliminary

Section	Effect	QRC comment	Recommendation
S2	Commencement date (earlier of assent date or 30 January 2012)	Does not leave much time for review of such a complex, contentious and ground breaking Bill.	Commencement on July 2012 would allow more time for sober review and genuine consultation.
S3 and S4	Apparent definition change in SCL from "the best cropping land" to "land highly suited for cropping".	This loosening of the definition may reopen the case for potential new future cropping land areas in the future. As the trigger maps and zones are based on a different definition, do they need to be redrawn to reflect this new definition?	Revert to the consistent definition of SCL as "the best cropping land", or preferably the original "best of the best cropping land".
S6(c)	Electricity transmission, but not generation, is excluded from the Act.	There is a small exception for some renewable energy projects (S285).	QRC recommends that electricity generation is also excluded from the Act and that geothermal energy is included in the definition of renewable energy (S285)
S6	Set out exclusions from the Act.	Note that some of the exemptions (under SPA) are not listed here but are listed under S290.	A note which set out the exemptions that will apply under SPA would help make the application of SCL easier to understand.

Section	Effect	QRC comment	Recommendation
S6(e)(ii) (sic – listed as the second ii)	The role of the Coordinator General is excluded (except for where the CG undertakes or directs other Government bodies to undertake works - i.e. traditional public utility and transport works) or facilitates development in a State Development Area	The private sector also undertakes these types of traditional public works for projects declared under the Act to be infrastructure facilities of significance (IFS)	QRC would argue that an IFS (section 125(1) (f) of the SDPWO Act) needs to be exempt from the policy because they also deal with socially/economically important linear infrastructure traditionally developed to provide public utility type services. An added criteria that the IFS must also be a Significant Project may be appropriate.
S9(3)	The new concept of decided non-SCL is an important one and it is defined on the basis of the updating the decision register and not a decision being taken.	Depending on the time taken to update the decision register, this lag may trip up some projects.	Amend the section so that a decision can be given immediate effect. Also, make it explicit that a development assessment process cannot impose conditions on areas that are “decided non-SCL”.

Section	Effect	QRC comment	Recommendation
S11	Five SCL principles – protection, avoidance, minimisation, mitigation and productivity	Aspects of these SCL principles are new and it is unclear what effect they will have. They are considered in developing the protection conditions S100(2), but no guidance is provided to the chief executive as to how they are to be considered. This principle needs to be clarified as, for example, it does not recognise the key differences in considerations for protection areas and management areas. The minimisation and mitigation principles could be interpreted to mean that potential project footprint area changes in a SCL management area that are prohibitively costly (e.g. in financial or environmental impacts) are reasonably practical because they result in small (or even negligible) positive SCL impacts.	See specific comments below.
S11(2)	The protection principle sees SCL "takes precedence over all development interests".	This principle, which excepts only exceptional circumstances, seems very broadly stated. Does SCL take precedent over Regional Ecosystems, Wild Rivers, remnant vegetation or habitat for protected species?	This principle should be covered by S(3) purpose of the Act (once the definition of SCL is addressed).

Section	Effect	QRC comment	Recommendation
S11(4)(b)	This definition of the minimisation principle is important as it requires restoration back to “pre-development condition” and not to SCL status.	This may require doing some upfront benchmarking on what constitutes the pre-development condition and making sure the regulator is comfortable with that target before any disturbance to SCL occurs.	The draft SPP (5 August 2011) was inconsistent in using both “back to SCL status” and “pre-development condition”. The drafters seem to have chosen the more administratively complex threshold.
S11(6)	The definition of the productivity principle	The definition seems entirely circular and it is unclear what this principle adds to the focus on productivity under mitigation	Remove the section
S14(1)	The definition of permanent impact (preventing the land from being cropped for at least 50 years) includes an example which calls out both the (a) density of drilling or wells and (b) cumulative impacts.	Both of these will suggest approaches for farmers to argue that their land is permanently impacted.	QRC is concerned that the section gives the regulator broad powers to apply SCL without the benefit of definitions or thresholds. It is not clear where in the Act the cumulative impact mentioned example is given effect.
S14(1)(c)(i)	The definition of permanent impact includes a range of activities “deemed” to be permanent impacts – regardless of any actual impact or capacity to restore SCL.	For a process based on science to hardwire in an assumption based on existing practice suggests a lack of faith in the science or the process of SCL.	Delete the section.

Section	Effect	QRC comment	Recommendation
S14(1)(c)(ii)	The definition of permanent impact includes storing any mine waste, “including for example tailings dams, overburden or waste rock dams”.	This would seem to preclude any effort at rehabilitation – for example sorting and storing topsoil. The section doesn’t specify that the impact is on the SCL, for example if a conveyor belt is used to remove overburden for storage on a non-SCL site, is this intended as a permanent impact?	Delete the section.
S14(3)	A regulation can prescribe an activity or development that is deemed to cause a permanent impact	This allows the introduction of arbitrary rules regarding the impact on SCL by certain developments or activities regardless of their actual impact.	Delete the section.
S14(4)(a)(i)	The definition of permanent impact includes not just SCL, but also potential SCL.	This change in the definition introduces significant ambiguity into the application of the Act, which introduces administrative risks for proponents.	The definition of permanent impact should be made at a point in time and not be subject to later changes in the scope of the land covered. Delete all references to potential SCL in this section.

Section	Effect	QRC comment	Recommendation
S14(3)(a)	A regulation can prescribe either (i) a type of development or (ii) a density.	This section gives very broad powers to subsequent regulations, which may follow the lead of S14(1)(c)(i) and (ii) in prescribing activities based on assumptions not science.	Delete. The ability to prescribe categories of activity should at the least require legislative change, not by regulation. "Permanent impacts" should in any case be determined on the basis of whether individual developments will in fact have a permanent impact on SCL or whether SCL can in fact be restored – not deemed impacts across broad categories of activity.
S14(4)(a)(ii)	A regulation can prescribe a development that is deemed to cause temporary impact	This allows the introduction of arbitrary rules regarding the impact on SCL by certain developments or activities regardless of their actual impact.	Delete the section.
S17(2)(b)	Defines "resource activity" as encompassing activity on a proposed tenure.	Giving the SCL Act the ability to regulate activities on an exploration tenure which has not yet been granted will complicate the administration of the Act and may well have unintended consequences.	QRC is concerned that the proponent may be required to undertake SCL testing or benchmarking on exploration tenure that has not been granted – so that the land access provisions do not apply.
S18(c), (d) and (e)	Defines a resource activity in terms of tenure.	It is unclear if the definition is intended to apply to all tenures or just production tenures	The Act should specify the specific tenures that apply – eg ML, PL.

Section	Effect	QRC comment	Recommendation
S20 (b) and (c)	The definition of source authority for resource project allows either the tenure (b) or the environmental authority (c) to be used.	This drafting, when read in concert with how conditions are to be applied, could see tenures or EAs conditioned (or both). The combination with S22(b) will have unintended consequences.	The Act should apply only to the EA. S20(b) should be deleted.
S22(b)	The triggers for the Act are very broadly applied – amendment, renewal or re-grant of a source authority (EA or tenure)	The interaction of the broad definitions in S20 and S22 could mean that any minor amendment to EA conditions could trigger a full review of SCL status with subsequent conditioning of tenure and EA.	The intent of the policy was that SCL assessment occurs at the time of application. It's not clear why DERM have sought to revisit these SCL applications so regularly. This will introduce a large and unacceptable regulatory risk for proponents.

Chapter Two – Identifying strategic cropping land

Section	Effect	QRC comment	Recommendation
S26(1)	Defining the trigger map.	While QRC supports the updating of the trigger map (and protection / management maps in S28), the maps should apply at the time of application and the extent of these maps at that time should be captured.	The Act should anticipate a process of tracking changes to these key maps so that applications are not subjects to retrospective assessments. S38(2) needs to be more explicit if this was the intent.
S27(1)(b)	Includes the capacity for new cropping zones (S35(1) to establish new zonal criteria	QRC is concerned at the risk of new cropping zones and criteria emerging in the future without the rigours of legislative scrutiny.	New zones should be established by legislative amendment.
S32(1)(c)(ii)	Defines an amendment to a map as minor if it is only to ensure that no lot is partly inside a zone or area shown on the map.	QRC is concerned that subsequent lot amendments should not automatically result in an amendment to the map.	Amend the drafting to clarify that the section does not apply to changes in lot boundaries.
S33	Permits the Chief Executive to make minor amendments to maps.		Suggest that when the Chief Executive amends maps that they are also responsible for contacting affected landholders and resource tenures holders.
S34(3)	Allows the Chief Executive to add or remove potential SCL to the trigger map via regulation.	This clause requiring regulation needs to exempt the regular process of updating the trigger maps to reflect registered decisions – otherwise the decision register and maps will be out of step. Delete references to potential SCL.	Amend the section to allow validation decisions on SCL to be updated on all maps immediately.ie no need for a new regulation to update in this case.

Section	Effect	QRC comment	Recommendation
S34	The Chief Executive can amend the trigger map.	The ability to have new potential SCL springing up near existing projects is a real concern. Delete references to potential SCL.	Existing projects and tenures need to be grandathered when new areas are included in the trigger maps.
S35	The Minister can amend, by regulation, a zone or protection area.	Given the consequences of these amendments, QRC believes that such changes should require legislative amendments. The amendment of a protection zone should require the approval of Governor in council.	Delete the section.
S36	Ministerial notice of zone or protection area amendment	If these zones or protection areas are to be amended, QRC believes the Minister should be required to contact all tenures holders and land holders in the affected area.	Reword section
S36(2)(d)	A submission period of 21 days	QRC suggests that this is too short given the likely complexity of changes that could be proposed.	QRC suggests a period of a 30 business days after the landholder/tenure holder has been contacted.
S40(2)(c)(i)	Sets out when applications for an SCL decision may not be made.	It is not clear why an application is prohibited if a cropping history decisions had already been made for the property.	Reword the section to clarify the intention, otherwise this risks perverse results for gaming applications.

Section	Effect	QRC comment	Recommendation
S41(d)	An eligible person for making an application can include someone who has applied for resource tenure (even under tender).	Conducting an SCL assessment may require access to the land, but the land access provisions assume a granted tenure. Further the definition of tenure in schedule 2 is unusual, it is not clear if it applies to all tenures or just production tenures.	The explanatory memorandum provides some greater detail in defining which applicants may be eligible (but this does not seem explicit in the Act). The definition of tenure must be clarified.
S45	Applications in a management area must be property based.	The reason for applying the cropping history at the property level is unclear, especially as the property may be far larger than the parcel of potential SCL. Some properties may consist of thousands or tens of thousands of hectares while potential SCL may be a much smaller parcel of say 100ha within the property. If the potential SCL area within the property has not been cropped within the test period, then it should not pass the test.	This approach would seem to weaken the link between the specific plot of potential SCL and the ability to demonstrate a history of cropping. QRC recommends deleting this section.

Section	Effect	QRC comment	Recommendation
S49	Defines the process of testing required cropping history.	The interpretation of the test has been dramatically watered down, to the point where it is difficult to imagine that the test will provide any useful filter at all. Specifically: (1)(b) perennial crops existed on the property. (2)(a) the use of the rest of the property is not considered. (2)(b) the crops do not need to be for sale. It is ridiculous that an abandoned orchard, from which fruit has not been harvested during the last decade, and which has gone wild, could be treated as having a 'cropping history' over that period.	While the drafting does not contradict the original policy of 3 or more crops, the very loose definition of crops over the entire property mean that the test is unlikely to filter out any land. QRC recommends deleting 2(a) and (b) and substantially rewriting 1(b).
S50	Defines things that are not crops for required cropping history.	Section should explicitly exclude crops grown on the property for the purpose feeding of livestock on the property. The previous policy statements have not indicated that the legislation would have such a broad coverage (i.e. to include fodder). The schedule 2 dictionary also refers to any form of cultivated crop for any purpose including for example, fodder.	As a minimum, it should be made clear in section 50 and the dictionary that crops for the purpose of livestock food which they forage for themselves is excluded. Preferably, all types of fodder should be excluded.
S53	The chief executive has 14 days to decide whether to accept an application.	This seems a very generous allocation of time.	QRC suggests that it be done within 3 business days.

Section	Effect	QRC comment	Recommendation
S54(2)	If an application is not made by the owners, then "the applicant must give all owners… a copy of the application".	It could be difficult to ascertain whether someone is negotiating to purchase land from the State – item 1(c) of the definition of 'owner'. Also, for item (h), this could include unregistered tenants (ie, for leases under 3 years) and various other unregistered interests.	QRC suggests that this section be amended to be "make best endeavours to contact the owners". This should be satisfied by writing to persons named in publicly searchable land and resource tenure registers, at the addresses provided in such registers.
S55(3)	A sufficient description of the land requires that a member of the public can identify the land's location without conducting a land registry search.	This section requires the applicant to take responsibility for the comprehension ability of the public – some examples would help reduce this risk.	Some examples in notes would help reduce the uncertainty about what level of information is required.
S55 & 56	Requires public notice and submissions period in all situations	This may unnecessarily delay development even if the land is clearly not SCL (e.g. has already been permanently alienated or not cropped for a long period of time)	Chief Executive of DERM should have discretion to decide to not publicly notify if evidence that land doesn't pass cropping history test is satisfactory to the Chief Executive and the applicant is also the landowner. In this case the Chief Executive should be able to go straight to the decision
S61(2)(b)	If land is decided as compliant with the zone criteria, it can meet the minimum size criteria by being contiguous with (i) SCL or (ii) potential SCL or (iii) land the chief executive reasonably believes is highly suitable for cropping (although presumably not either SCL or potential SCL).	The drafting of this clause would seem to completely undermine the policy intention of having a minimum land size as part of the assessment. Delete application to 'potential' SCL.	Delete this section. It seems to introduce a new SCL principle of contiguity by stealth, which has never been discussed in any of the policy documents.

Section	Effect	QRC comment	Recommendation
S61(2)(b)(iii)	If land is decided as compliant with the zone criteria, it can meet the minimum size criteria by being contiguous with (iii) land the chief executive reasonably believes is "highly suitable for cropping".	This clause references the definition of SCL in S4, but ignores the fact that this land is defined as potential SCL and hence covered under (ii). As drafted (iii) would seem to give extraordinary discretion to the chief executive.	Clause (iii) must be deleted. The references to "any of the land" S61 and 2b must be deleted.
S62	Provides for the minimum lot size and width for the five cropping zones.	These minimums, which perform as a de facto SCL criteria, do not need to be set out in legislation. If the legislation was less rushed, they would be in a regulation.	Remove from legislation.
S62(d)	Allows for a minimum lot size for new cropping zones to be set out in regulation.	Given the far-reaching consequences of establishing new zones, QRC believes that they should be established under legislation (after a genuine consultation process and full RAS).	Delete this section.
S65 (2)	Provides that a cropping history test decision for a property must apply to the whole property	See comments regarding S45 above. There will be many cases where only a small part of a property will have a cropping history. It is therefore inappropriate to decide that a cropping history applies to the whole property.	Clause must be amended to enable cropping history decisions to be made for sub-property areas
S65(6)(b)	If land is decided as compliant with the zone criteria, it can meet the minimum size criteria by being contiguous with eligible land.	The drafting of this clause would seem to completely undermine the policy intention of having a minimum land size as part of the assessment.	Delete this section. It seems to introduce a new SCL principle of contiguity by stealth, which has never been discussed in any of the policy documents.

Section	Effect	QRC comment	Recommendation
S70	The chief executive has 3 months to make a validation decision	This seem like an inordinately long time and inconsistent with the brief period allowed for submissions.	QRC suggests that 15 business days should be sufficient.
S71(1)(b)	Who the chief executive should notify after reaching a validation decision	The chief executive should be responsible for contacting all tenure interests affected by the decision.	Reword section so that the Chief Executive contacts all affected tenure interests.
S73	Recipient of a validation decision may appeal to the Planning and Environment Court.	For resource projects, the Land Court would seem to be the appropriate body.	Amend the section to allow resource projects to appeal to the Land Court.
S72(3)(a)	The chief executive is required to give a description of the land to the land registrar.	S55(3) requires applicants to provide a sufficient description of the land – such that a member of the public can identify the land's location without conducting a land registry search.	Amend the section to require the chief executive to also provide a sufficient description of the land.

Chapter Three – Developments on strategic cropping land or potential strategic cropping land.

Section	Effect	QRC comment	Recommendation
S76	Sets maximum penalties including gaol time for developing on SCL or potential SCL and having a permanent impact	It would seem odd to treat the protection of SCL and potential SCL as equivalent, particularly given the ability to generate new potential SCL via regulatory amendments. As separate penalties for corporations and individuals is not prescribed, s 181B (of the Penalties and Sentences Act 1992 (Qld) provides the penalty will be 5 times the amount stated for an individual.	Reword the section A maximum penalty should be stated for a corporation. If it is the same for an individual then this should be clarified.
S81(1)	A regulation can make a code about how resource activities may be carried out on SCL.	This will be very important for exploration and other low-impact activities.	Some examples would help clarify the intent of this section.
S84	An applicant can elect to treat potential SCL as SCL.	While this section falls under a heading of Development Approvals, DERM indicated that this path is also open to resource projects. Note that if an applicant elects to not treat potential SCL as SCL, and in fact the land is SCL, the applicant will be subject to penalties under s 76.	It is difficult to see any benefits from this approach.
S90(2)	If land becomes SCL or potential SCL after an application is made, then this change in status is considered in making a decision.	The status of SCL should be as at the time of an application, not moving the goal posts after the investment in an EIS has already been made.	Rather than flirting with retrospectivity, an application should be assessed under the rules that applied at the time of application. Should not apply to 'potential' SCL.

Section	Effect	QRC comment	Recommendation
S98(1)(b)	This section allows the regulator to impose SCL protection conditions on either the tenure or the EA.	The definition in S20 of either the tenure or the EA as the source authority means that the regulator can attach conditions to either – without reference to which was being considered. This clause is particularly alarming when read in conjunction with S22(b) which means an application for an amendment, renewal or re-grant can trigger the assessment. QRC feels there is a lack of understanding of mining tenure in this provision or an opportunity to capture further developments that otherwise would be exempt.	QRC recommends that the conditions are attached to the EA and not the tenure.
S99	Defining the scope of SCL protection conditions including 99(1)(c) "require the applicant to do, or refrain from doing, anything else the chief executive considers is necessary".	It is difficult to see the reason for such broad powers.	QRC recommends that the section be deleted.
S99	S99(2) allows the chief executive to decide the form and amount of financial assurance limited only by S99(3) the total amount the State may incur because of any possible noncompliance. These assurances can be changed under S104(2) with 28 days notice.	It is difficult to see the reason for such broad powers.	QRC recommends that the powers be defined more carefully so that they are consistent with the financial assurance process for all rehabilitation conditions.
S102(3)	If SCL protection conditions are inconsistent with any other condition, the SCL provisions prevail.	Given the lack of clarity about what the SCL protection provisions might be, this seems like a very broad power to grant the chief executive.	Delete this section.

Chapter Four – Exceptional circumstances

Section	Effect	QRC comment	Recommendation
S113	The ability to prescribe a class of development as exceptional circumstances (eg see S285 for “major” renewable energy (but not geothermal)).	This is an odd clause in that it limits itself S113(3) from applying to mineral or petroleum projects by defining them as excluded from being prescribed.	This is a very complex section, and it’s hard to understand a legitimate need for it.
S116	(1) allows the Coordinator-General to decide if a significant project meets the exceptional circumstances test, otherwise (2) it is the Minister (DERM).	QRC supports the Coordinator Generals role and suggests that the OCG should retain the power to decide exceptional circumstances for all projects.	Delete S116(2) so that the Coordinator General administers the exceptional circumstances test.
S118	The significant community benefit test S118(a) is defined as “overwhelmingly significant opportunity” and also requires (b) that the benefit outweighs the state’s interest in protecting SCL.	The choice of drafting seems to substantially strengthen the test.	QRC recommends that the word “overwhelmingly” be removed.
S127	Defines the criterion for an alternative site in a very generous manner that ignores many of the realities of resource projects including (1)(a) tenure, 2(a) ownership, 2(c) profitability, 2(d) class or grade of resource (including an example that the Government proposes to ignore the differences between thermal and coking coal), and 2(e) proximity to infrastructure.	The alternative site test for resource projects seems designed to be unable to be passed whereas the equivalent test for development applications S129(3) is quite loose.	QRC recommends that S127(2)(d) should be deleted. The other clauses of this section need a substantial rewrite.
S128	Sets out the criteria for significant community benefit so as to require S128(1)(c) significant adverse impacts if the development is not carried out and S128(2) limiting the consideration to be broader than economic.	Combined with the drafting in S118, these sections seem to go beyond the intent of the policy in making it very difficult for any non-community project to satisfy these tests.	QRC recommends a substantial rewrite of these sections so that they better match the original policy.

Section	Effect	QRC comment	Recommendation
S130	Allows for appeal to the Planning and Environment Court.	For resource projects, the Land Court would seem like a better destination.	Enable appeals to the Land Court.

Chapter Five - Mitigation

Section	Effect	QRC comment	Recommendation
S131	In effect mitigation efforts will be centralised and overseen by Community Advisory Groups (S145).	QRC is concerned that companies who are investing in mitigation expertise onsite will be put into a situation of tendering to the Advisory group for their own mitigation funding.	S131 seems too narrowly defined and should include scope for investment by the company onsite so that mitigation measures S133(1) are recognised as mitigation.
S132	Allow for the mitigation value of land (per hectare) to be set by a regulation.	QRC is curious to know how these values will be determined and when the draft regulation might be released.	The Act should usefully set down some principles to guide the development of this critical regulation. Further, there can be no sensible discussion on the impact of the mitigation provisions until it is understood what rate will be prescribed in the regulations. Further discussion on mitigation should continue at this time.
S135	Set out the mitigation criteria.	QRC is concerned that the S135(1)(e) focuses on the number of agribusiness rather than perhaps value of production of area under crop. This seems like the wrong metric and could skew decisions from the Advisory group.	Reword S135(1)(e) to focus on the value of agricultural production.
S137(4)	Mitigation responsibilities endure, even if the land is found not to be SCL.	This drafting seems perverse. QRC would argue that if the land is found not to be SCL, there is no need for mitigation, so the Advisory group's spending can cease.	QRC recommends that this clause be deleted.

Section	Effect	QRC comment	Recommendation
S143(2)	The chief executive (DEEDI) can make payment from the mitigation fund only with the advice of the Advisory group.	QRC is concerned that the Advisory group is being forced into micromanaging progress payments on mitigation work.	QRC recommends that this clause be deleted.
S149(e)	The chief executive can make guidelines giving advice about any matter relating to this chapter.	That clause seems very broad.	QRC recommends that this clause be deleted.

Chapter Six – Power to require compliance

Section	Effect	QRC comment	Recommendation
S153	An authorised person can issue a restoration notice	These are very broad powers which rely on the reasonable belief of an authorised person which allow a very directive intervention.	QRC would prefer to see a more graduated system of notices described in this section.
S160(4)	If the chief executive can amends the restoration notice, for example because of a change in technology.	28 days to respond seems insufficient to assess a potentially complex request	QRC suggests that the time for response is set by agreement between the chief executive and the recipient.

Chapter Seven – Investigation and enforcement

Section	Effect	QRC comment	Recommendation
S170	The process of appointing an authorised person	Part of the delegation from chief executive to authorised person derives from their instrument of appointment S170(1)(a). In this case, QRC suggests that it is reasonable that these instruments of appointment are made public.	QRC suggest that the clause be amended so that the scope of authority of the authorised person is disclosed whenever these powers are exercised (perhaps as part of the identity card in S173).

Chapter Eight – Miscellaneous provisions

Section	Effect	QRC comment	Recommendation
S227	Establish a Science and technical Implementation Committee		QRC would like to have seen the Committee review the SCL criteria.
S236(2)	Allows the decision maker to consider any criteria the decision maker considers relevant unless specifically precluded under (3).	Given that the Act already ascribes sweeping powers in a number of areas, this section risks compounding the unintended consequences.	QRC recommends that this clause be deleted.
S237 (2)	Allows the decision maker to consider any criteria the decision maker considers reasonable and relevant including the precautionary principle.	This clause seems even broader than 236 and it is without the limits imposed in S236(2).	QRC recommends that this clause be deleted.
S269	Review of the Act between 30 January 2014 and 30 January 2016.	The discussion of the scientific committee refers to a two-year review.	QRC suggest that the review date be set as 2 years after the date of assent, otherwise the review could fall due in two parliamentary terms time.

Chapter Nine – Transitional provisions

Section	Effect	QRC comment	Recommendation
S275 and S278	Defines the exclusion of the Act for transitional projects.	QRC is concerned that the wording of these exclusions is not sufficiently robust to deliver the policy outcome described in the Government's transition factsheet – specifically 278(2)	QRC recommends deleting the phrase "apart from permanent impact restriction applies for the applications" from 278(2)
S279(b)(i)	Certificate of application had been issued by 31 May 2011.	In the policy, QRC understood that there would be a period in which the certificate could be issued by August 2012. (Transition fact sheet)	QRC recommends that this clause be amended to allow for a period for the certificate of application to be issued to match S281(1)(b) below.
S281(1)(b)	Sets a deadline for applying for a mining lease of 23 August 2010.	In the policy decision, this deadline was 23 August 2012.	QRC understands that this is just a typographical error and will be corrected.
S281(c)	Requires the applicant to have held the tenure on 23 August 2010.	The definition of tenure holder will be very important as it is common to hold tenure through joint venture and other collective arrangements. Further, the test as drafted does not envisage tenure being held within company groups. For example, it is common practice for tenures to be held by different companies who all have common ownership.	QRC suggests that the test should be that substantially the same tenure holder held both the production tenure and the continuous EP or MDL on 23 August 2010. The legislation needs to recognise the tenement application being held by the holder of the adjoining ML, or …*held by a related body corporate(s) (within the meaning of the Corporations Act) of the holder of one of the holders*.

Section	Effect	QRC comment	Recommendation
S279-282	The transition provisions don't recognise the Government's 2008 decision on oil shale and the McFarlane tenure.	Part 7AAB of the Mineral Resources Act imposed a moratorium on development of QER's McFarlane tenements. Section 318ELAD provides that during the moratorium a mining tenement can not be granted, but otherwise the status quo of the tenements are preserved.	In the absence of the moratorium, QER would have finalised an EIS terms of reference before 31 May 2010 and been eligible for transitional provisions. QRC suggest that the Bill amend the MRA to specifically include SCL in the status quo provisions of Part 7AAB.
S285(2)	Defines renewable energy as wind, solar energy or biomass, but does not mention geothermal.	QRC can see no reason to exclude geothermal as a renewable energy source	QRC recommends that the definition is amended to include geothermal energy.

Chapter Ten – Amendment of legislation

Section	Effect	QRC comment	Recommendation
S291	Amends the SPA to exclude a range of agricultural uses of the land from the SCL policy.		For the sake of clarity, QRC would prefer that these exemptions are noted under S6.
Schedule 1	Provides the zone criteria in legislation	Given the open questions over these criteria***** and the inevitable need to amend these criteria as implementation proceeds, QRC suggests that these criteria thresholds should be in regulation not legislation. * See QRC's independent review of the proposed criteria.	Remove the detail of the specific zone thresholds from the legislation and address in regulation instead.
Schedule 2	Definition of contiguous	This definition does not include the sense in which a lot can be contiguous – for example in S61(2)(b) – whereby a watercourse or road does not break the contiguity for applying zonal criteria.	QRC suggests that for consistency that the same definition be applied for the purposes of transition mechanisms.
Schedule 2	Definition of tenure	The definition of tenure seems to rely on "the holding of land under a resource Act". This definition is very important for a whole host of rights for a resource project during the SCL process and as such it is very essential that the definition reflects the full range of exploration and production tenures which are possible.	QRC suggests that the definition include a specific list of all the different tenure types under resource legislation.

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

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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 <u>all</u> 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

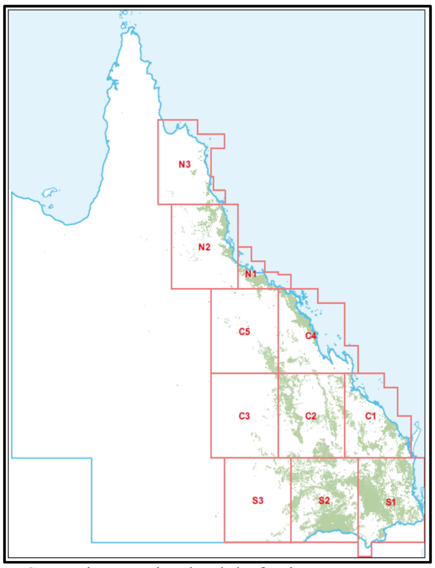

Fig. 1. Strategic cropping land draft trigger map composite.
(Source: DERM 2010b)

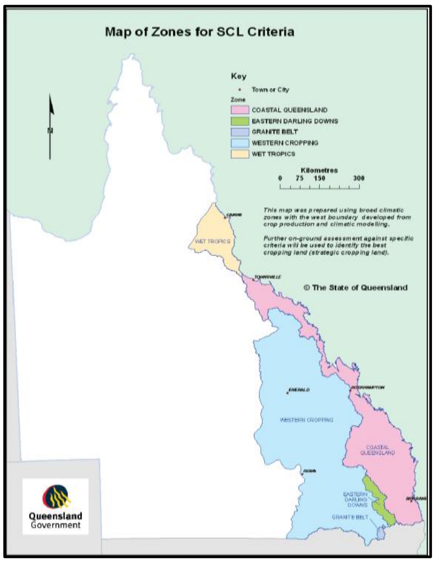

Fig. 2. Strategic cropping land zones.
(Source: DERM 2011b)

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

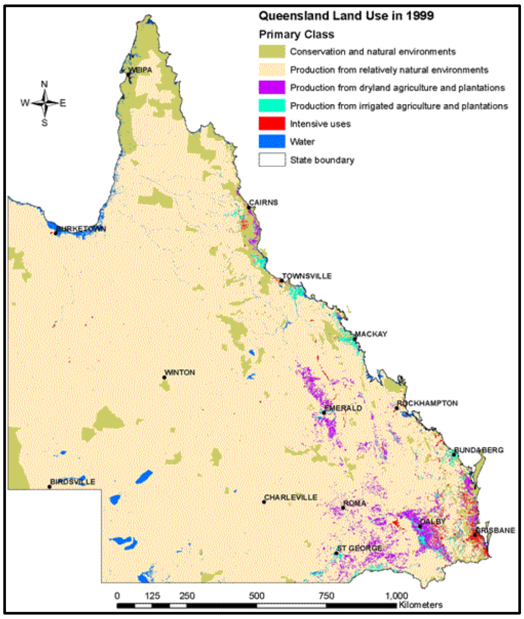

Fig. 3. Primary classifications for 1999 Queensland land use (DERM 2008).

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

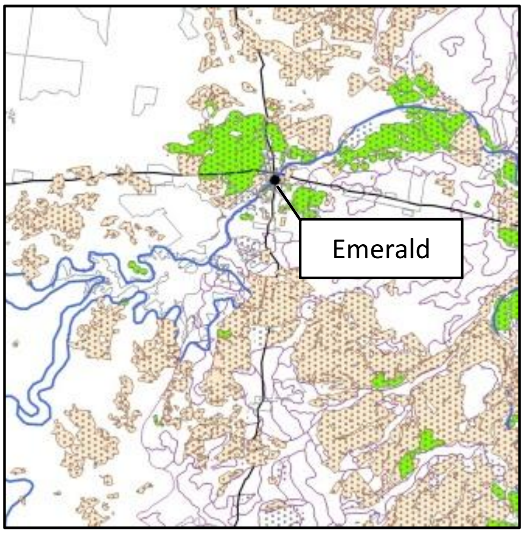

Fig. 4. Detail of trigger map in the vicinity of Emerald. (Brown colour is dryland cropping land use and green colour is irrigated cropping land use (DERM 2008), purple lines denote mapped soil units, grey dots indicate SCL trigger map layer (DERM 2010a)

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.

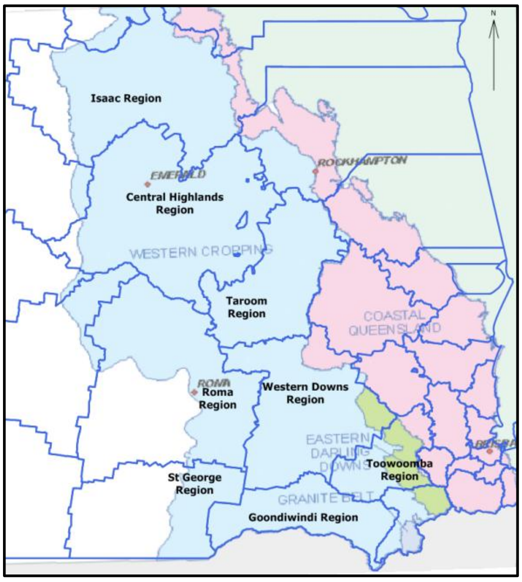

Fig. 5. Detail of zone map showing Western zone (light blue) and encompassed regions (DERM 2011b).

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).

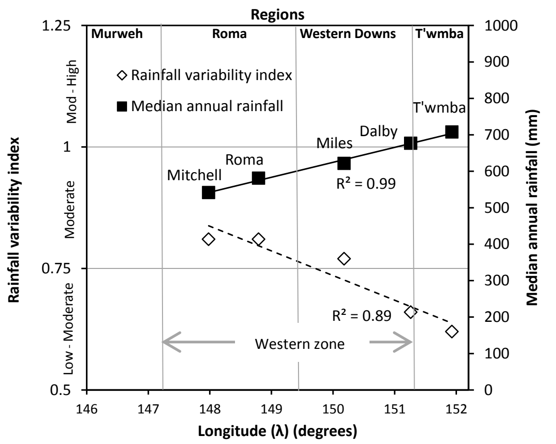

Fig. 6. Rainfall variability index (RVI) (P≤0.001) and median annual rainfall (P≤0.05) on a west-to-east transect from Mitchell to Toowoomba (BOM 2011).

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.

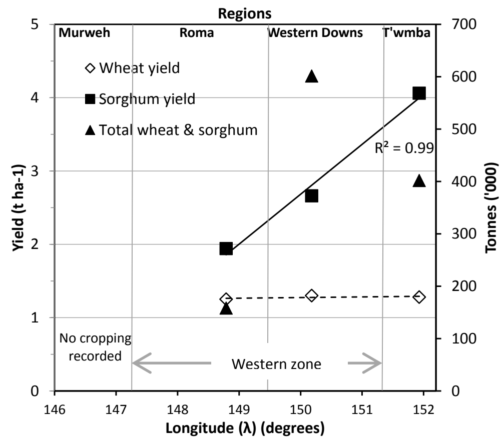

Fig. 7. Mean yields and total tonnes of wheat and sorghum (P≤0.1) (2000 – 2008) on a west-to-east transect from Mitchell to Toowoomba (ABS 2011a).

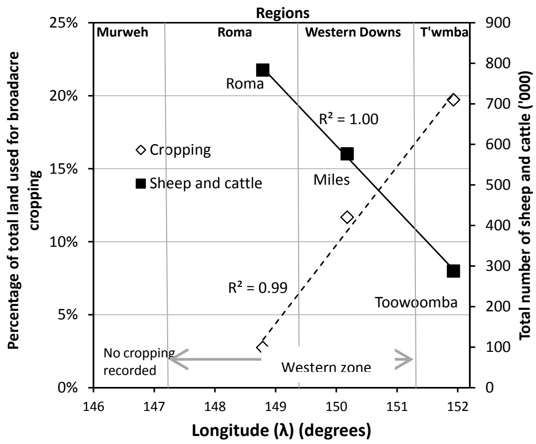

Fig. 8. Cropping area (P≤0.001) and total livestock numbers (P≤0.1) on a west-to-east transect from Mitchell to Toowoomba (ABS 2008a).

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)	Effective-ness (%)	*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

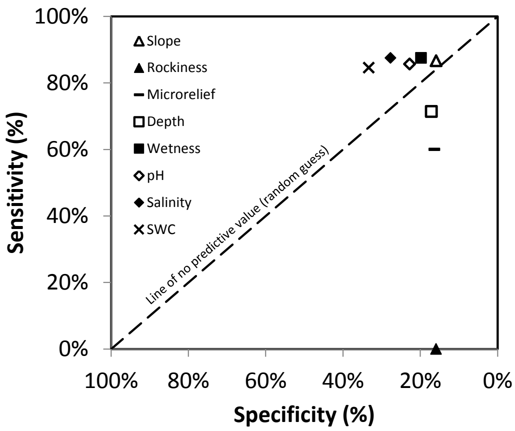

Figure 9. Binary classification model plotted in receiver operating characteristic (ROC) curve space, indicating relative predictive value of each criterion applied at 128 sites. Note the criterion below the line of discrimination have no predictive value in identifying SCL.

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)	Effective-ness (%)	*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).

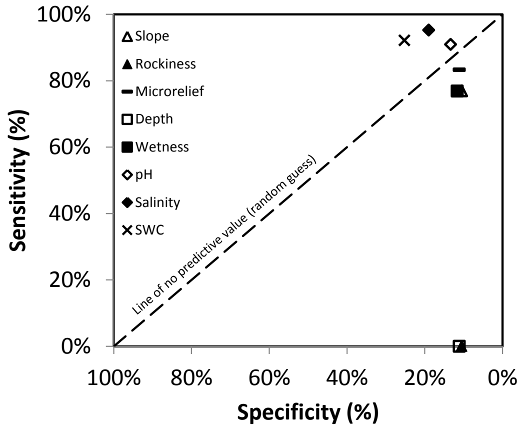

Figure 10. Binary classification model plotted in receiver operating characteristic (ROC) curve space, indicating relative predictive value of each criterion applied in the Western zone. Note the criterion below the line of discrimination have no predictive value in identifying SCL in the Western zone.

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.

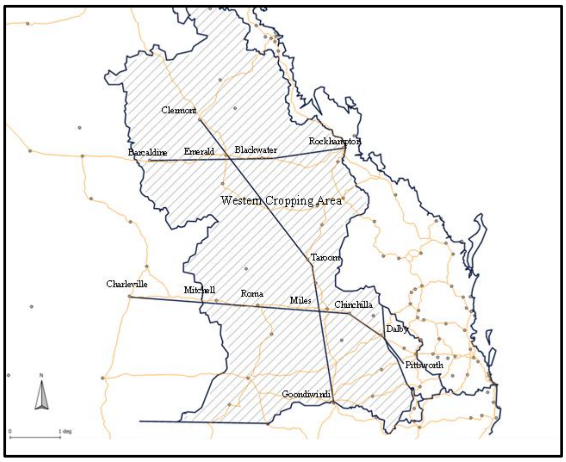

Fig. 11. Location of transects used for crop model simulations in APSIM.

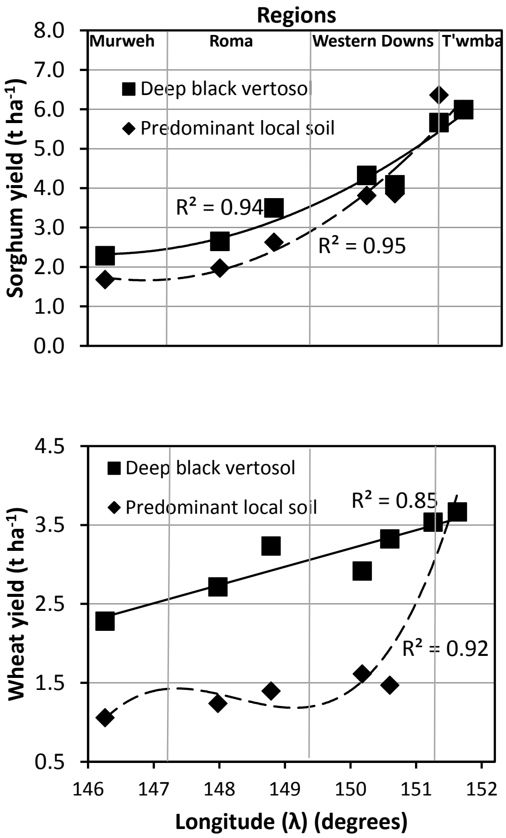

Fig. 12. Effect of climate on sorghum and wheat yields on a west-to-east transect within the Western zone.

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).

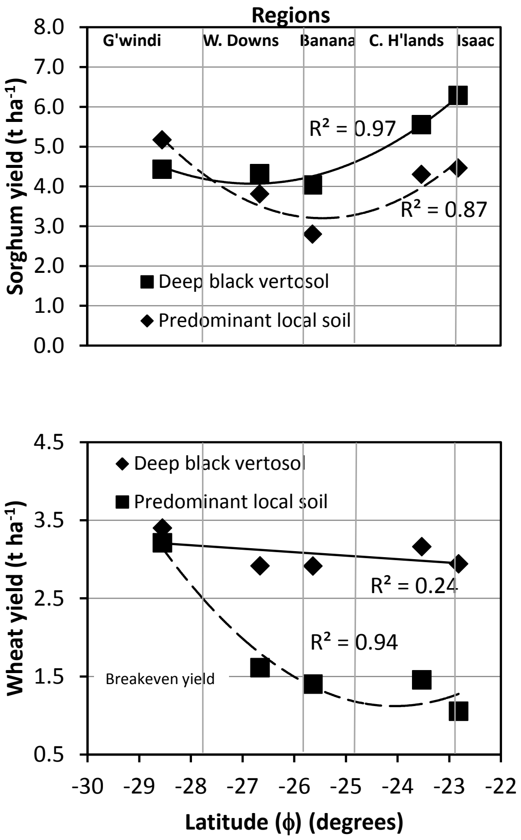

Fig. 13. Effect of climate on sorghum and wheat yields on a south-to-north transect within the Western zone.

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).

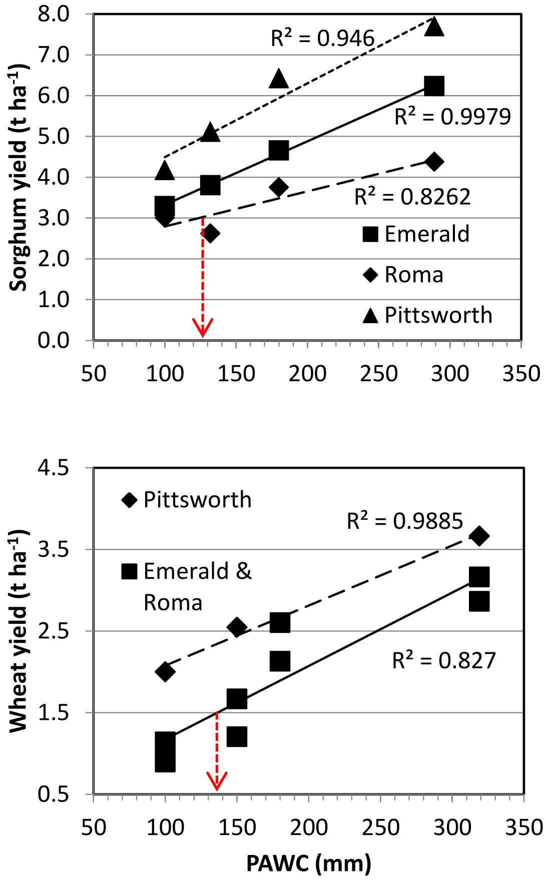

Fig. 14. Effect of PAWC on sorghum and wheat yields within the Western zone.

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.

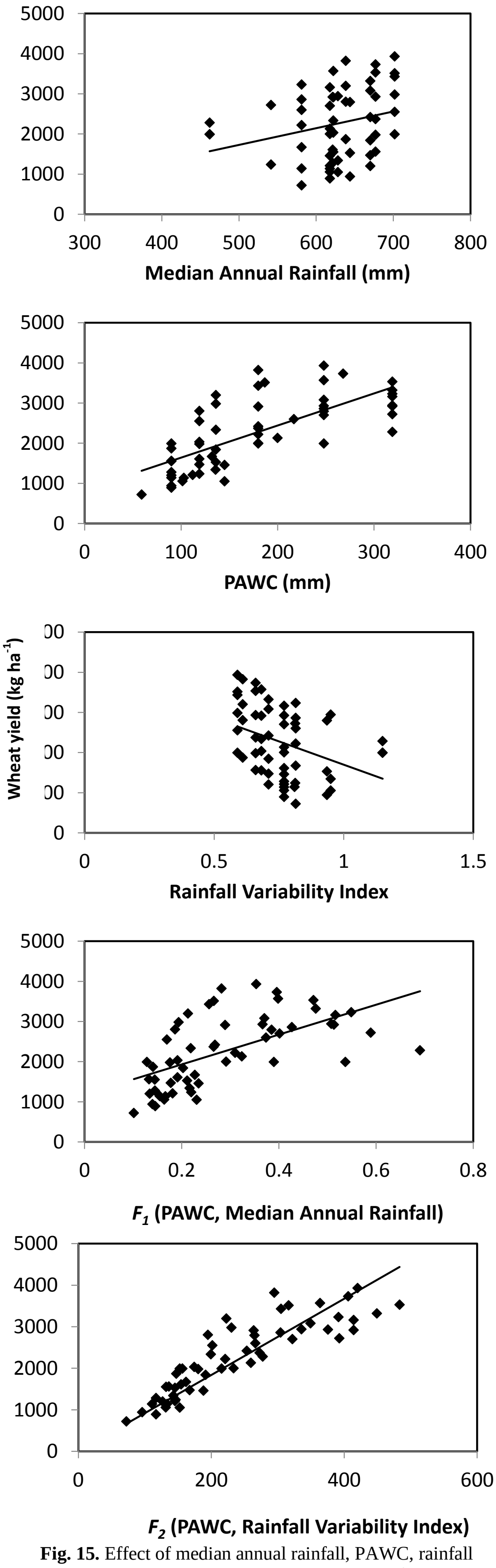

Fig. 15. Effect of median annual rainfall, PAWC, rainfall variability index, F_1 (PAWC, median annual rainfall) and F_2 (PAWC, rainfall variability index) on modelled wheat yield

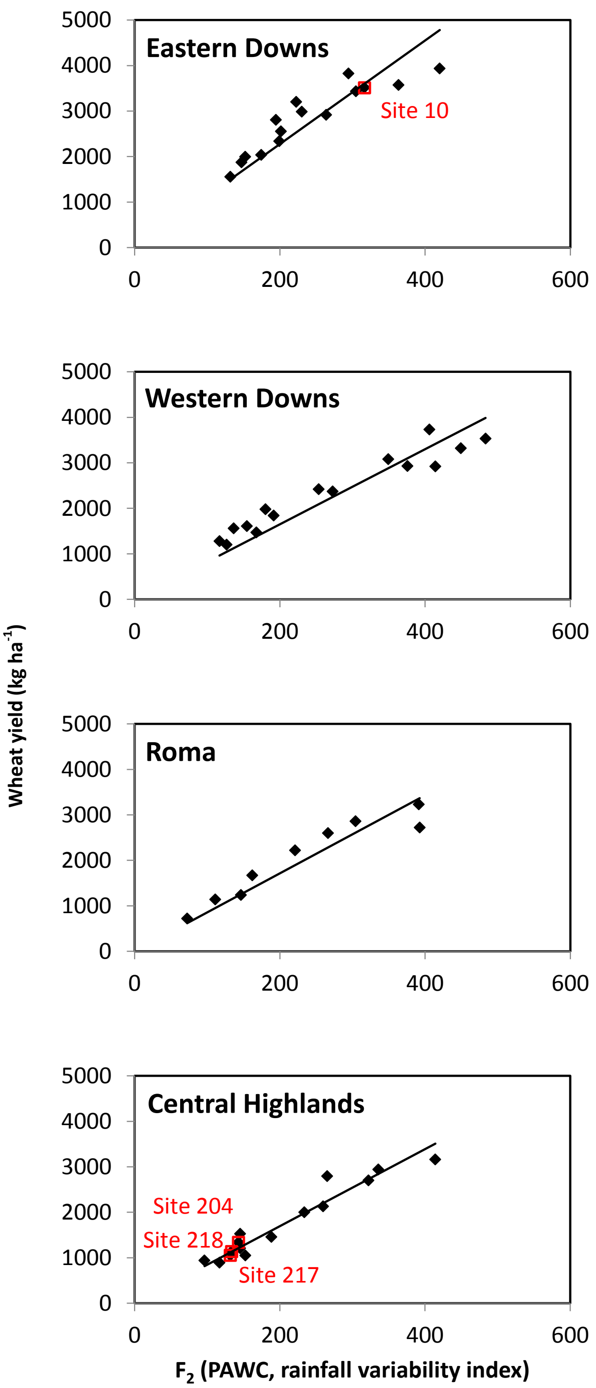

Fig. 16. Effect of F_2 (PAWC, rainfall variability index) on modelled wheat yield for each region. □ indicates soil from Government's SALI database also used in DERM (2011c).

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	***

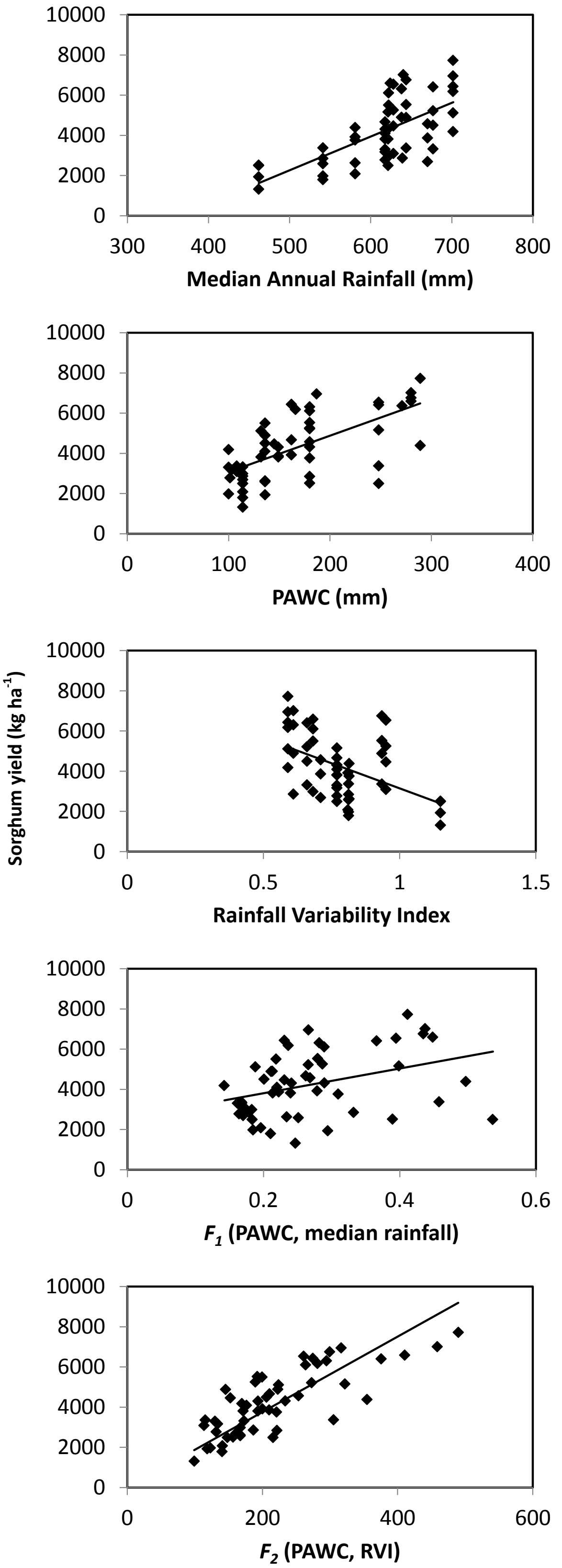

Fig. 17. Effect of median annual rainfall, PAWC, rainfall variability index, F_1 (PAWC, median annual rainfall) and F_2 (PAWC, rainfall variability index) on modelled sorghum yield

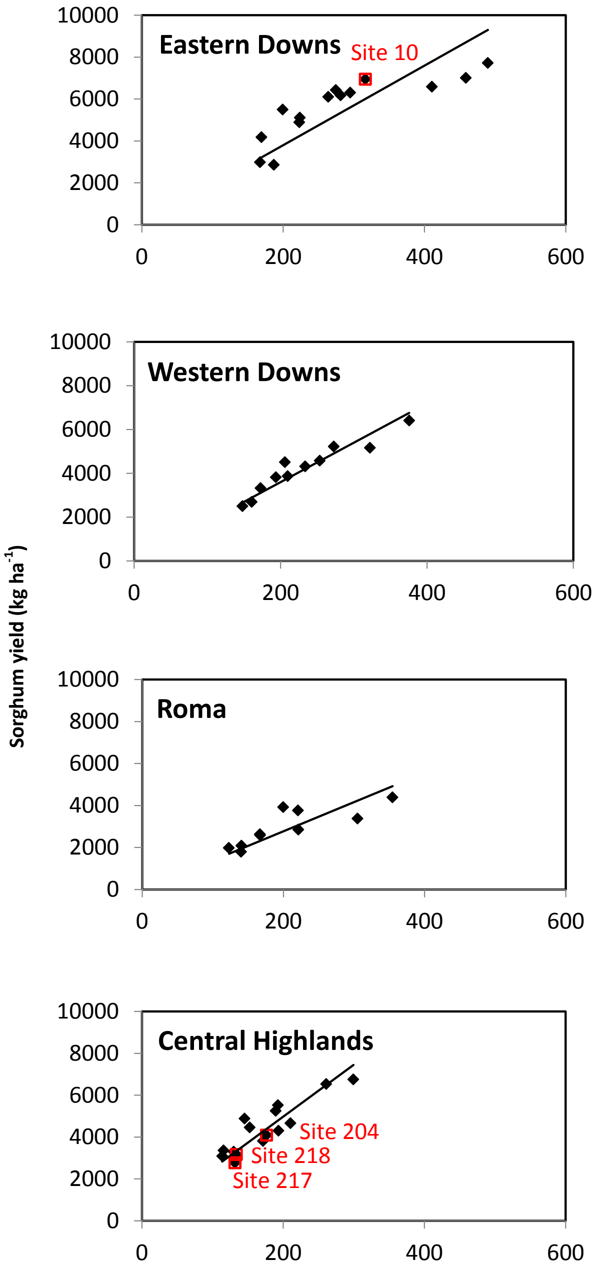

Fig. 18. Effect of F_2 (PAWC, rainfall variability index) on modelled sorghum yield for each region. ☐ indicates soil from Government's SALI database also used in DERM (2011c).

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.

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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.