Burnett Mary Regional NRM & Climate Adaptation Plan 2015

Land and Soils Asset Background Report

Burnett Mary
August 2015

This report has been prepared by Burnett Mary Regional Group staff in consultation with Land Resource Officers of the Department of Natural Resources and Mines.

Contents

1.0 Overview – Description and values

Living soils develop over time from the interaction of climate, geology, topography and the biological relationships between plants, animals and micro-organisms. In the Burnett Mary a complex distribution of regional soils has resulted. Apart from narrow strips of young alluvium deposited by rivers and streams, and coastal sand-mass deposits, the majority of the region has comparatively old undulating to hilly landscapes.

Effective land management practices and adoption of industry Best Management Practices (BMPs) relies on understanding landscape and soil processes. Management aims to maintain good soil health and land condition which in turn will maintain soil/land productivity whilst avoiding degradation; and reduce fragmentation of agricultural land to maintain long-term economic viability and avoid land use conflict.

Ultimately, improving land condition through effective planning and innovative/adaptive management (particularly with respect to climate variability) will enable continuing agricultural production, biodiversity conservation, functioning of ecosystem services, urban development, mineral and gas resource extraction, and improved surface, ground and marine water quality.

2.0 Asset Delineation

The Soil Resource Management Units (Table 1) developed by the Queensland Government, groups soil based on inherent similarities in chemical and physical properties and management aspects.

Table 1 - Soil Management Units

Asset Code	Asset Description
SR 1	Dermosols (sandy surface) includes non-sodic Chromosols/Kurosols/Kandosols
SR 2	Dermosols (sealing loamy surface) includes non-sodic Chromosols/Kurosols/Kandosols
SR 3	Dermosols (structured clay/clay loam surface)
SR 4	Ferrosols
SR 5	Hydrosols (sandy surfaced)
SR 6	Hydrosols (sealing loamy surfaced)
SR 7	Hydrosols (structured clay/clay loam surface) including Organosols
SR 8	Rudosols/Tenosols (loamy)
SR 9	Sodosols (loamy surface) including sodic Chromosols/Kurosols
SR 10	Sodosols (mod deep (>0.5m) sandy surface) including sodic Chromosols/Kurosols
SR 11	Sodosols (shallow (<=0.5m) sandy surface) including sodic Chromosols/Kurosols
SR 12	Tenosols/Rudosols/Podosols (sandy)
SR 13	Vertosols

SR1, SR2 & SR3: The Dermosols are predominantly moderately deep to deep, permeable, gradational to uniform textured soils on a diverse range of geologies and landforms. Water holding capacity is moderate and nutrient supply is predominantly low to moderate. The structured clay/loam group may have high fertility with high water holding capacity especially when developed on intermediate to basic geologies or alluvium. These soils occur extensively in near coast areas and are widely used for agricultural production under irrigation. Subdivision of the soil units is based on surface texture which refl ects moisture supply, nutrient status and vulnerability to climate variability.

SR4: Ferrosols are deep to very deep strongly structured, highly permeable clay soils high in free iron developed mainly on basic geologies such as basalts. These highly productive soils are very deep and permeable. They have moderate to high water holding capacity and nutrient levels; and are used extensively for cropping, mainly in the South Burnett, with smaller areas scattered throughout the Burnett and Mary Catchments.

SR5, SR6 & SR7: Hydrosols are seasonally wet to permanently wet soils (i.e. wet for >3 months in the major part of the profile) occurring mainly in the higher rainfall coastal/near coastal areas in lower landscape positions. These soils are not intensively developed, but where used for agriculture the land has been extensively drained and modified by levelling. Subdivision of the soil units is based on surface texture which reflects nutrient status, Soil Organic Matter accumulation and vulnerability to climate variability.

SR8: Rudosols and Tenosols (loamy) are generally very shallow/rocky soils developed on upper slopes and crests of a diverse range of geologies. Due to their inherent low productivity, these soils are predominantly not developed, used mainly for extensive grazing, forestry and conservation.

SR9, SR10 & RS11: Sodosols are texture contrast soils with a sandy to loamy surface abruptly changing to impermeable, dispersible sodic clay subsoil. These soils occur on a range of sedimentary, metamorphic and acid to intermediate igneous rocks with generally gently undulating to undulating topography. Due to their inherent chemical and physical constraints, these soils are not extensively developed for cultivation, but used mainly for grazing and native forestry. Subdivision of the soil units is based on surface texture which reflects moisture supply, nutrient status and vulnerability to climate variability.

SR12: Tenosols/Rudosols/Podosols (sandy) include a broad group of soils with predominantly deep to very deep, highly permeable, nutrient-deficient sandy textured profiles generally associated with sandy alluvium, coastal sand masses and some sandstone and granite geologies. The more fertile soils developed on alluvium are often developed for agriculture while the remainder are used mainly for extensive grazing, forestry and conservation.

SR13: Vertosols are moderately deep to very deep cracking clay soils developed on alluvium and clay-forming geologies. Soils in the Burnett Mary region have moderate to high fertility with high water holding capacity often over impermeable sodic subsoil. These soils are extensively developed for cropping and grazing.

Fig.1 shows the distribution of the Soil Management Units in the Burnett and Mary Catchments.

Table 2 lists the dominant land uses for each soil management unit. Overall, the more productive soils (Dermosols, Ferrosols and Vertosols) have a higher proportion (%) under cropping and sugar cane. The Land Use Groups are based on the 2009 Queensland Land Use Mapping completed by the Queensland Government and grouped based on similar land use management practices. For example the "Forestry" group includes plantation forestry and all lands designated as State Forests, while "Grazing" includes all lands with introduced pastures and vegetation communities used for grazing of native pastures. "Cropping" includes cultivated lands for all crops and horticulture excluding sugar cane and plantation forests.

Figure 1 - Distribution of Soil Management Units in the Burnett Mary Region

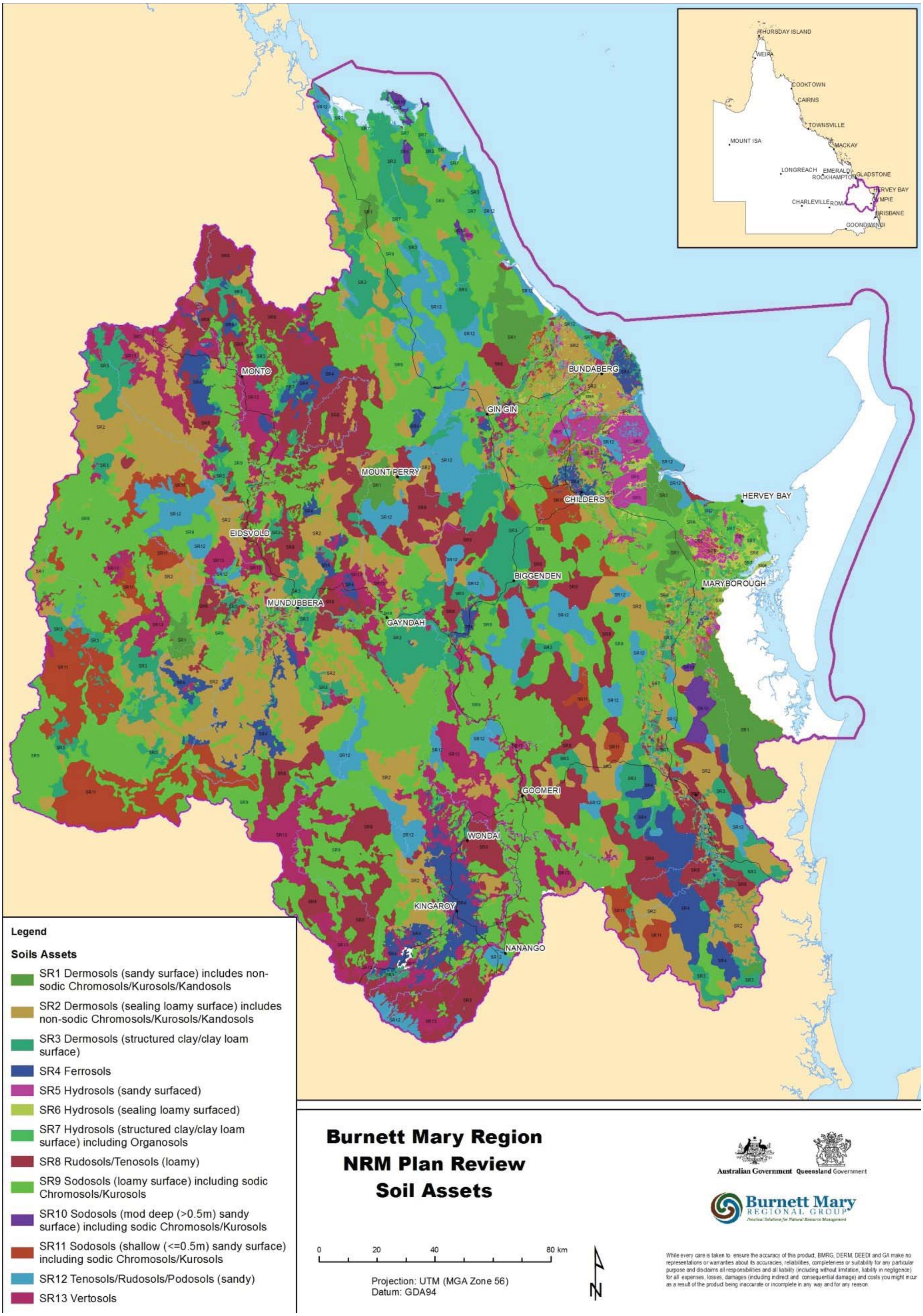


Table 2 - Dominant land uses for each Soil Management Unit

Asset Code	Asset Description	Land Use Group	Land Use Area (Ha)	% of Total Asset
SR 1	Dermosols (sandy surface) includes non-sodic Chromosols/ Kurosols/Kandosols (Total area 200 180 ha)	Cropping	573	0.3
		Forestry	80134	40.0
		Grazing	81140	40.5
		Sugar Cane	6277	3.1
SR 2	Dermosols (sealing loamy surface) includes non-sodic Chromosols/Kurosols/Kandosols (Total area 915 700 ha)	Cropping	11413	1.2
		Forestry	128956	14.1
		Grazing	616180	67.3
		Sugar Cane	24854	2.7
SR 3	Dermosols (structured clay, loam surface) (Total area 75 350 ha)	Cropping	5285	7.0
		Forestry	23974	31.8
		Grazing	23974	31.8
		Sugar Cane	6983	9.3
SR 4	Ferrosols (Total area 224 740 ha)	Cropping	33036	14.7
		Forestry	59328	26.4
		Grazing	96156	42.8
		Sugar Cane	10208	4.5
SR 5	Hydrosols (sandy surfaced) (Total area 58 210 ha)	Cropping	301	0.5
		Forestry	7402	12.7
		Grazing	11915	20.5
		Sugar Cane	7434	12.8
SR 6	Hydrosols (sealing loamy surfaced) (Total area 39 660 ha)	Cropping	355	0.9
		Forestry	1616	4.1
		Grazing	13154	33.2
		Sugar Cane	5576	14.1
SR 7	Hydrosols (structured clay/clay loam surface) including Organosols (Total area 33 670ha)	Cropping	19	0.1
		Forestry	58	0.2
		Grazing	13500	40.1
		Sugar Cane	3531	10.5
SR 8	Rudosols/Tenosols (loamy) (Total area 712 110 ha)	Cropping	2182	0.3
		Forestry	70204	9.9
		Grazing	519341	72.9
		Sugar Cane	577	0.1
SR 9	Sodosols (loamy surface) including sodic Chromosols/Kurosols (Total area 1 618 910 ha)	Cropping	14125	0.9
		Forestry	256248	15.8
		Grazing	1182854	73.1
		Sugar Cane	11161	0.7
SR 10	Sodosols (mod deep (>0.5m) sandy surface) including sodic Chromosols/Kurosols (Total area 23 220 ha)	Cropping	0	0
		Forestry	11357	48.9
		Grazing	3266	14.1
		Sugar Cane	206	0.9
SR 11	Sodosols (shallow (<=0.5m) sandy surface) including sodic Chromosols/Kurosols (Total area 260 130 ha)	Cropping	494	0.2
		Forestry	251446	96.7
		Grazing	221	0.1
		Sugar Cane	1549	0.6
SR 12	Tenosols/Rudosols/Podosols (sandy) (Total area 352 710 ha)	Cropping	609	0.2
		Forestry	266040	75.4
		Grazing	412	0.1
		Sugar Cane	2695	0.8
SR 13	Vertosols (Total area 381 330 ha)	Cropping	59504	15.6
		Forestry	6374	1.7
		Grazing	299047	78.4
		Sugar Cane	5188	1.4

3.0 Potential Climate Futures

The Soil Management Units of the region were assessed by an External Expert Panel to determine the vulnerabilities to climate change. The detailed results of the assessment are available from BMRG, however it was deemed that in general, Land and Soil Resources of the region were sensitive to the following climate change exposure indicators:

- temperature increases
- increasing lengths of dry periods
- Spring rainfall decrease
- more frequent and intense fires (measured as an increase of very high fire weather conditions (Forest Fire Danger Index FFDI)
- increased frequency of intense rainfall events.

Under a Potential Future Climate at 2030 and 2090 for RCP 4.5, the following Land and Soil Resources would likely be vulnerable (Table 3). For RCP 8.5 where emissions would continue to rise throughout the 21st century, the potential future for 2030 would be similar to the RCP 4.5. However, the potential futures under RCP 8.5 at 2090 would result in major to extreme effects on all soil and land resources resulting in a major decrease in land productivity and economic sustainability, and threats to biodiversity and water quality.

Table 3 - Potential vulnerabilities of the Land and Soil Resource under two climate scenarios.

Climate Scenario	Potential Climate Future 2030	Potential Climate Future 2090
RCP 4.5	Some increase in soil temperature reflecting atmospheric temperatures but productivity largely unaffected, Vertosols have significant linear increase due to inherent dark soil colours. All soils with some to significant increase in drought periods affecting soil surface cover and productivity, soil organic matter and landscape hydrology particularly shallow soils, sandy surfaced soils and Hydrosols. Some decrease in soil moisture reflecting spring rainfall decrease and reduced surface cover, Sodosols more affected. Minor to some effects on the soil organic matter content, surface cover and erodibility due to more frequent and intensive fires with moderate effects on the Sodosols and high effect on the structured Hydrosols due to lower water table and loss of organic matter. Some increase in soil erosion in all soils due to more intensive rainfall events, with a high increase on the erodible Sodosols due to reduced surface cover, loss of soil organic matter, increasing run-off and decreasing structural stability.	Significant increase in soil temperature and reducing productivity. All soils with significant to major increase in drought periods particularly soils with shallow rooting depths and Hydrosols, while Dermosols, Ferrosols and Vertosols least affected. Significant to major decrease in soil moisture reflecting spring rainfall decrease, Sodosols more severely affected. Some effects on the soil organic matter content, surface cover and erodibility in the more productive soils due to more frequent and intensive fires, with very high effects on the Sodosols and extreme effect on the structured Hydrosols due to lower water table and loss of soil organic matter. Some to moderate increase in soil erosion in all soils due to more intensive rainfall events and reduced surface cover and loss of soil organic matter, with extreme increase on the erodible Sodosols due to increasing run-off and decreasing structural stability.

Increased soil temperatures will reflect atmospheric temperatures with minimal to some increase in expected effects on production, mainly through plant germination and establishment. The highly productive Vertosols with their inherent dark colour will be moderately affected. Adaptation may involve earlier/later planting dates, retention of crop residues to reduce surface temperatures and evaporation rates, and modified technology such as tolerant varieties.

Increased length of dry periods and droughts will affect all soil productivity and surface cover through reduced soil moisture availability. This will lead to a reduction in soil organic matter, structural stability and soil nutrition. Unless soils are carefully managed, the expected increase in the length of dry periods will result in a downward spiral of soil fertility, increased erosion and dramatic changes in landscape hydrology. Adaption has involved contraction of dryland cropping areas to the "better" soils, rapid destocking at the start of droughts, maintaining soil health (SOM, pH, nutrition, structure), maintaining surface cover and residues to reduce erosion and retain soil moisture, and flexibility in management options. The soils with lower water holding capacity (shallow/rocky soils such as Rudosols/Tenosols, sandy textured soils, and soils with restricted rooting depth such as Sodosols) are most susceptible. Any changes in landscape hydrology will severely affect Hydrosols resulting in dramatic reduction in soil organic matter and probably changes in vegetation communities/biodiversity. The lowering of coastal water tables will result in the oxidation of sulfidic deposits in acid sulfate soils resulting in increased release of acid drainage and associated contaminates resulting in land and water acidification, loss of production, and aquatic/estuary/marine habitat loss. However, under RCP 8.5 where sea levels would rise significantly, much of the coastal acid sulfate soils would be inundated without significant actions to exclude the rising sea level. Under this scenario (RPC 8.5), the impacts of low lying acid sulfate soils would be reduced.

Decreased spring rain will reduce soil moisture supply for plant growth, having generally similar but less severe affects as increased length of dry periods (as described above). As our spring rains are generally variable with "small" amounts relative to the main summer dominant rains, the effects of decreased spring rain is less pronounced than other areas in Australia where spring rains are essential for early planting of summer crops or to "finish-off" winter crops. The effects are reduced productivity and surface cover through reduced soil moisture availability. This will lead to reduced soil organic matter, structural stability and soil nutrition, increased erosion and some changes in landscape hydrology.

More frequent and intense fires are expected to occur on all landscapes especially when "good" seasons are followed by drought. Fire results in the direct loss of surface cover, soil organic matter and associated soil health (pH, nutrition, structure), increased runoff and erosion and changed landscape hydrology. The soils at risk are generally the more fragile soils such as the shallow/rocky Rudosols/Tenosols, and Sodosols. Persistent burning will result in land degradation and changes in vegetation communities and biodiversity. The structured Hydrosols generally correspond to soils with very high surface organic matter, and under certain circumstances the formation of peats. Although peats do not occur in the Burnett and Mary Catchments, they do occur in the adjacent Fraser and Cooloola sand masses. Due to changes in coastal hydrology, these communities are prone to burning, resulting in a dramatic and severe permanent loss of organic matter, habitat and biodiversity.

Increased frequency of intense rainfall events will affect productivity and soil health of all Soil Management Units to varying degrees. As described above, increased temperatures, decreased rainfall, increased drought and more frequent fires all influence the amount of surface cover, soil organic matter and other soil health (pH, nutrition, structure), all resulting in lower land productivity, increased run-off, changed landscape hydrology and reduced soil health. Therefore, any increase in the frequency of intense rainfall events will result in increased erosion and delivery of sediment and nutrients to our waterways. This in turn reduces the capacity of our landscapes to support agricultural production, environmental services and healthy habitats. The soils at severe risk are generally the more fragile soils such as the shallow/rocky Rudosols/Tenosols, and Sodosols.

A benefit of a generally drier environment will be the reduction in the extent and severity of salinity as water tables will generally lower, with the leaching of salts to lower in the soil profile. However, as with the 2010-2013 "wet" seasons, the rapid rise in water tables in all landscapes resulted in extensive expressions of salinity, generally the most severe since the mid-1970s. Management of salinity relies heavily on maintaining good vegetation growth (trees and pastures); however as described above, climate variability threatens the productivity and health of all landscapes particularly landscapes that have been cleared, under cultivation and irrigation.

Under all climate scenarios, any inundation of land from sea level rise would result in a significant increase in carbon sequestration in the soil. These changes are not mentioned here as they become part of the Marine Asset.

4.0 Land and Soil Resource Strategic Direction, Targets & Desired Outcomes

The visions and targets listed in the NRM Plan are non-statutory. They seek to achieve and align with long-term sustainability outcomes and principles referred to in the Wide Bay Burnett, Central Queensland and South East Queensland Regional Plans and other relevant State and Commonwealth Plans. The Vision, 2020 Target and Desired Outcomes for each of the Land and Soil Resource indicators are summarised in Table 4.

Table 4 - Land and Soil Resource aims

Asset	Strategic Direction	2020 Targets	Desired Outcomes
Land and Soil Resource	Land condition and soil health within the region will be maintained or improved.	Salinity extent and severity is maintained at the 2015 baseline.	Mobilisation of salts in the landscape results in no further loss of agricultural productivity or negative impacts from saline runoff into adjacent vegetated communities and waterways
		Soil acidification is maintained at the 2012 baseline for agricultural land.	Soil pH in agricultural land is managed to maintain or reduce negative productivity and soil health impacts.
		Soil organic matter is maintained at the 2012 baseline for agricultural land.	The biological, chemical and physical properties of agricultural soils are not compromised by loss of soil organic matter.
		Sheet erosion risk, stream bank erosion risk and gully erosion extent and severity do not exceed 2015 baseline levels.	Land productivity is maintained and total soil loss and infrastructure damage is reduced. Nutrient and sediment loads in streams will be reduced by 20% to support the Reef Plan.
		The extent of acidification caused by the disturbance of Acid Sulfate Soil does not exceed the 2015 baseline.	Disturbance of Acid Sulfate Soils (ASS) will be avoided. In cases of disturbance, the impacts of ASS disturbance (acid drainage and pollutants in waterways, and infrastructure damage) will be effectively managed.
		Extent of suitable Cropping Land (i.e. cropping, horticulture and plantation forestry) is maintained at the 2015 baseline.	The potential for agricultural production on cropped and undeveloped land, suitable for crop production, will be preserved.
		Ground cover of Grazing Lands is maintained at the 2015 baseline.	The productivity and sustainability of Grazing Land will be aided through implementation of Best Management Practices and Grazing Land Management.

NOTE: Sections 4.1 to 4.7 provide a description of each of the Land and Soil Resource indicators, and a brief conceptual outline explaining the pressure and response relationships associated with each. Maps relating to each indicator are provided in Appendix A; however it is important to understand that these datasets represent the best information available at this time and may not necessarily accurately represent the specific indicator. For example, Salinity Hazard mapping is currently available, but the 2020 Salinity Target specifically relates to salinity extent and severity. For information about proposed indicator monitoring and evaluation strategies, refer to Section 6.

4.1 Salinity

2020 Target - Salinity extent and severity is maintained at the 2015 baselines.

Salinity extent and severity

Secondary salinity of our land resources is the accumulation of soluble salt in the soil or waters (surface and ground water) due to human activities. Salinity becomes an issue when the concentration of salt affects plant growth (crops, pastures or native vegetation), or degrades the soil or affects infrastructure. Secondary salinity becomes a water issue when the potential use of the water (including environmental needs) is limited by its salt content. Saline areas are also prone to erosion.

Measuring the expansion or contraction (extent in hectares) and intensity (salt concentration) of salt affected areas provides an effective tool for assessing changes in salinity status over time. It can also aid in determining risk of various landscapes (NLWRA, 2007).

Salinity extent and severity is linked with other land condition outcomes including improved soil fertility, reduced soil loss and improved water quality.

For the Burnett Mary the lack of available information on the current condition of salinity extent and severity requires the collection of baseline information. Until salinity extent and severity baseline data is available, 'salinity hazard' is used in combination with existing salinity site data and expert knowledge to identify areas where salinity may occur. Salinity hazard is based on the ranking and addition of inherent land and soil properties which include regolith salt store, recharge potential and discharge potential as outlined in the DNRM Salinity Hazard Assessment in the Burnett Mary and Western Catchments of the South East Queensland 2003. As salinity hazard does not change with changes in management or climate variability, it has no value as a monitoring tool. Available mapping is located in Appendix A.

Conceptual understanding of the pressure and response relationships

As salinity is the result of complex interactions between geophysical, climate and land use factors, land and water management aims to change the hydrologic equilibrium in sensitive areas. Excessively cleared landscapes naturally high in salts and under irrigation are at highest risk. Improved management activities seek to manage the ground water through improved plant growth (crops, pastures and trees), improved irrigation methods (water application, water quality and water table monitoring), soil and land management, and engineering solutions (e.g. drainage, resistant infrastructure). Understanding landscape processes is essential to improve management decisions, but avoiding development in sensitive areas is the best management.

The conceptual understanding of how salinity is expressed is illustrated below in Table 5. The first row of the table describes the process of how human activities and natural events put pressure on systems causing physical and chemical changes to the environment, which can be measured by assessing indicator condition and trend. Row two describes the assumptions about the scientific understanding of secondary salinity processes while row three describes the data necessary to monitor condition and trend.

Table 5 - Tool for identifying salinity extent and severity indicator and information needs

	Pressures		Physical / chemical / attitudinal changes	Indicator Condition & Trend
	Human Activity	Natural Events		
Process/Function of secondary salinity	Land use and land management (including clearing regulations) influence the amount of deep drainage.	Climate and landscape hydrology influence the amount of deep drainage and landscape processes.	Water table will rise as a result of increased deep drainage. In certain landscapes this rise can bring groundwater levels within 3m of the ground surface.	Change in extent and severity of surface salinity.
Assumptions	Land use is related to land management and land management is directly related to the amount of deep drainage in all landscapes. Clearing regulations effectively.	Landscape pressures are known. Rainfall and evapo-transpiration are key factors that influence the amount of deep drainage.	Groundwater systems are known and behave similarly throughout the catchment. Water tables to the surface cause salinity.	Assessment standards accurately reflect landscape processes. Surface salinity is an indicator of specified pressures and will reflect changes in pressures over time.
Information needs (data)	- Remnant vegetation - BGI - Land use mapping - Industry programs (BMP) - Incentive programs (BMP) - Extension services (e.g. GLM) - Permitted clearing extent	- Rainfall - Evaporation	Depth and salinity of groundwater.	Extent and severity of surface salinity.

4.2 Soil Acidification

2020 Target - Soil acidification is maintained at the 2012 baseline for agricultural land.

Soil acidification extent and severity

Soil acidity (as measured by pH) is a fundamental soil health indicator which is affecting significant areas of Australian cropping soils. Soil acidification is a natural process which is generally accelerated by the intensification of land management and use. Soil acidification is a major factor affecting many chemical and biological processes, and subsequently ecosystems processes. The process is responsible for reducing land utilisation options through reduced plant growth and productivity. Other onsite and offsite effects of soil acidification include:

1. loss of soil biota involved in nitrification
2. accelerated leaching of Mn, Ca, Mg, K and anions
3. induced nutrient deficiency and toxicities
4. breakdown and subsequent loss of clay minerals from soil
5. soil erosion as a result of poor plant growth in acid soils
6. mobilisation of heavy metals into water resources and the food chain
7. acidification of waterways as a result of leaching of acidic ions
8. increased siltation and eutrophication of streams and water bodies.

Measuring the expansion and contraction (extent in hectares) and intensity (how acid) of land affected by soil acidification provides an effective tool for assessing changes in soil acidification over time. Monitoring soil acidification will assist land managers, natural resource agencies and commercial organisations to understand the rate of soil acidification so that preventative and/or restorative measures can be implemented.

Soil acidification is linked with other soil health outcomes including improved soil fertility, reduced soil loss and improved water quality as listed above. Available mapping is located in Appendix A.

Conceptual understanding of the pressure and response relationships

Soil acidification is the result of interactions between geology, climate and land use and management factors. The major causes of soil acidification are:

1. rainfall and leaching
2. organic matter decay (releasing of organic acids)
3. harvest and removal of high yielding crops/pastures
4. long term fertiliser application (particularly over fertilising).

The conceptual understanding of how soil acidity forms is illustrated below in Table 6. The first row describes the process of how human activities and natural events put pressure on systems causing physical and chemical changes to the environment. These can be measured by assessing indicator condition and trend. Chemical composition/mineralogy of the parent material contributes various amounts of acidity/alkalinity to a soil and therefore to the soils' inherent buffering capacity. Row two describes the assumptions about the scientific understanding of soil acidification while row three describes the data necessary to monitor condition and trend.

Table 6 - Tool for identifying soil acidification indicator and information needs.

	Pressures		Physical / chemical / attitudinal changes	Indicator Condition & Trend
	Human Activity	Natural Events		
Process/Function of soil acidity	Land use and land management influence the amount of: 1. product removed from a site 2. excessive fertiliser use 3. Deep drainage.	1. Climate (rainfall) and landscape hydrology influences the amount of deep drainage. 2. Chemical composition/ mineralogy of soil parent material contribute various amounts of acidity and/or alkalinity	1. Deep drainage from excessive rainfall or irrigation removes basic cations from the soil causing increased acidity. 2. The weathering of soil parent material releases basic and or acid ions resulting in a change in soil acidity. 3. Unutilised ammonium based fertilisers result in soil acidification by adding H+ ions. 4. Continuous removal of vegetative material from a cropping/grazing system results in the loss of basic cations leading to soil acidity.	Change in extent and severity of soil acidification measured using soil pH
Assumptions	Land use is related to land management and land management is directly related to product removal, fertiliser use and deep drainage in all landscapes.	Rainfall and mineralogy of soil parent material are natural factors that influence soil acidity.	Soil acidification processes behave similarly where all climate and soils are equal.	Assessment standards accurately reflect landscape and land management processes. Soil acidification is an indicator of specified pressures and will reflect changes in pressures over time.
Information needs (data)	- Land use mapping (past and present) - Land management practices - Soil type information including soil buffering capacity information - Industry programs (BMP – Best Management Practice) - IWUP (irrigation water use plan) - Incentive programs (BMP) - Extension services (e.g. GLM – Grazing Land Management)	- Rainfall - Evaporation - Lithology - Soil biology	Measured soil pH across combinations of most common variables.	Extent and severity of soil acidity across common soil types and land uses

4.3 Soil Organic Matter

2020 Target - Soil Organic Matter is maintained at the 2015 baseline for agricultural land.

Soil Organic Matter (Soil Organic Carbon)

Soil organic matter (SOM) derived from decaying plants and animals plays an essential role in soil condition such as stable soil structure, effective nutrient supply, improved water availability, surface infiltration and profile permeability, healthy microbial and faunal activity and storage of carbon to buffer greenhouse gasses in the atmosphere. The associated interaction of biological, physical and chemical process is illustrated in Figure 2.

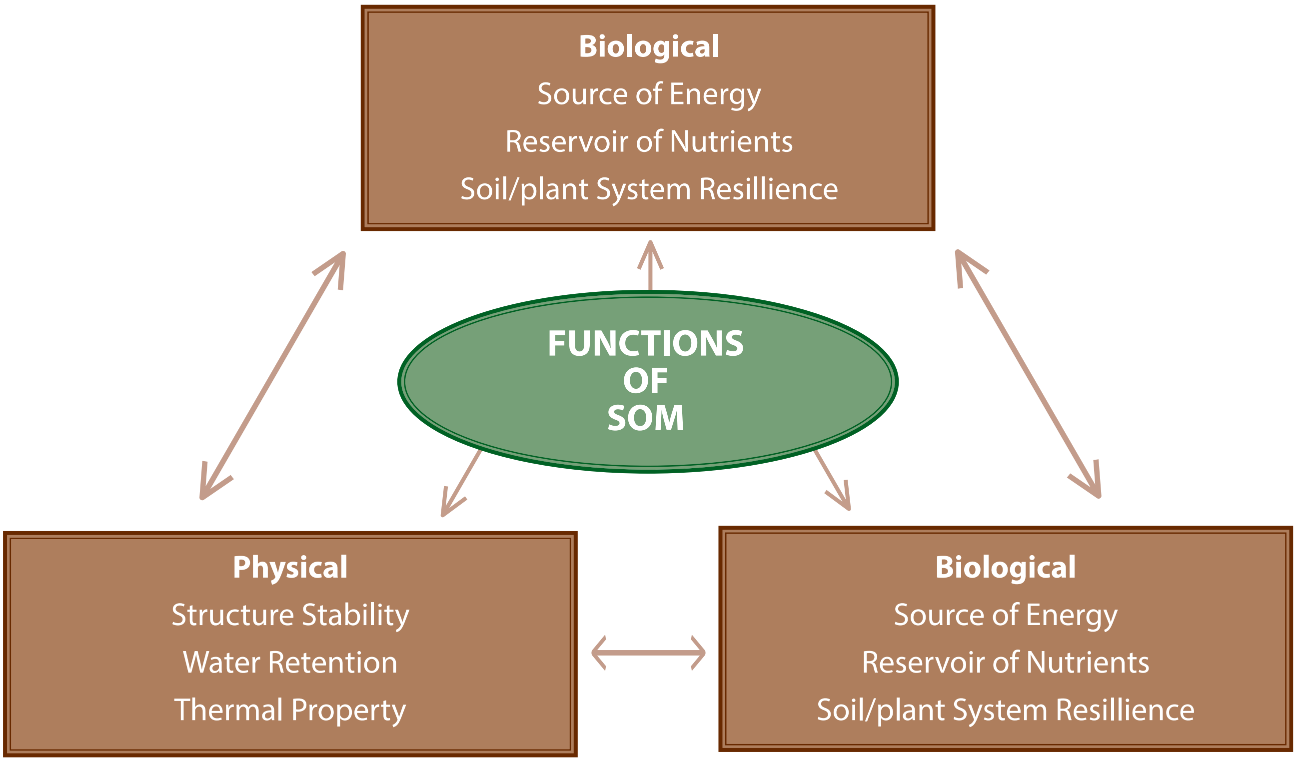


Figure 2 - Functions of Soil Organic Matter and their interactions

SOM is generally concentrated within the upper soil horizons where organic inputs occur. A number of land use factors influence the accumulation (gains) and mineralisation (losses) of soil organic matter including organic inputs, cultural practice (cropping, grazing, ploughing etc.) and climate.

The majority of soil organic matter is soil organic carbon (SOC). SOC is relatively simple to measure and provides a convenient tool for measuring changes in SOM, and therefore soil and land condition, over time. SOC is generally divided into three groups or pools which describe how reactive it is in the soil and how long it could be expected to remain. The three groups in order of decreasing vulnerability are:

- The labile (or active) pool – living biomass, partly decomposed organic matter.
- The humus pool – humic and fulvic acids and humates.
- The recalcitrant pool – highly protected organic matter (mostly charcoal).

The relative proportion of each pool is an indicator of soil health. While the percentage of recalcitrant SOC remains generally steady, in degraded soils both the labile and humus pools will be significantly smaller. It is generally accepted that to adequately understand SOC all pools require measuring. However, it is more common to measure total SOC and labile SOC as these measurements are quick, relatively low cost, and the difference represents mainly the recalcitrant pool.

Conceptual understanding of the pressure and response relationships

Management actions aim to maintain or improve SOM levels in our soils. Maintaining SOM levels is not easy as disruption of normal plant growth will reduce the supply of organic matter to the soil.

Cultivated soils are most at risk, with most cropped soil having approximately 50% of the SOC of soils under original native vegetation. Management that supports the target includes minimum tillage, retention of plant/crop residues, maintenance of soil fertility (chemical and physical), low temperature burning at appropriate times, rehabilitation of degraded areas and reduced land degradation such as salinity, erosion and soil contamination. The effect of each of these factors is specific to each different soil type considered. Available mapping is located in Appendix A.

The conceptual understanding of how SOM changes in the landscape is illustrated below in Table 7. The first row describes the process of how human activities and natural events put pressure on systems causing physical and chemical changes to the environment, which can be measured by assessing indicator condition and trend. Row two describes the assumptions about the scientific understanding of SOM while row three describes the data necessary to monitor condition and trend.

Table 7 - Tool for identifying soil acidification indicator and information needs.

	Pressures		Physical / chemical / attitudinal changes	Indicator Condition & Trend
	Human Activity	Natural Events		
Process/Function of SOM	Land use and land management influence the amount of organic carbon cycling in the soil profile.	Climate, soil type, vegetation cover and vegetation type influence the amount of stored organic carbon.	Reduced SOM levels result in soil health declines related to structure, moisture holding capacity, nutrient availability and erosion resistance.	Changes in percentage of SOM as measured by SOC.
Assumptions	Land use is related to land management and land management is directly related to the amount of cycling organic carbon in all landscapes.	The amount of cycling organic carbon is related to climate (rainfall, evaporation and temperature), plant growth, topography, soil type (texture, pH, fertility & parent material) and how they interact with land management techniques.	SOC levels behave in a uniform manner where all climate, soil, topographic and climate variables are equal.	SOC changes accurately reflect changes in land management practices over time. Assessment sites represent modal land uses.
Information needs (data)	- Land use statistics or mapping - History of farming or land clearing - Current vegetation mapping - BGI (Bare Ground Index)	- Climate data (temperature, rainfall, evaporation) - Vegetation coverage and type. - Soil type (parent material, soil depth etc.) - Topography (elevation, slope, rockiness) - Land use. - Geology	Measured concentrations of SOC across combinations of most common variables.	Extent and variability of SOC levels under a range of common land uses.

4.4 Erosion

2020 Target - Sheet erosion risk, stream bank erosion risk and gully erosion extent and severity do not exceed 2015 baseline levels.

Erosion Risk

Sheet & Stream Bank Erosion

Sheet erosion and stream bank erosion will be monitored by assessing Erosion Risk.

The risk of erosion is influenced by multiple pressures (natural and human) and as an indicator requires a variety of information inputs. Similarly, the effects of erosion spread across multiple spheres, and directly and indirectly affect multiple natural resource assets (including land resources; regional landscapes; coastal, estuarine and marine ecosystems; and terrestrial and freshwater ecosystems). More specifically, soil loss through erosion has significant environmental, economic and social implications which often cannot be reversed. For example, loss of topsoil inhibits crop and plant growth, interferes with farming operations and may damage infrastructure, while sediment-laden runoff and sediment deposition negatively impact on terrestrial and aquatic ecosystems, with repercussions throughout the agricultural, fisheries, tourism and conservation sectors.

As an indicator, Erosion Risk:

- is capable of showing trends over time (e.g. alteration to management or cover will directly alter erosion risk)
- is sensitive to change and is predictive (e.g. erosion risk is inherently predictive and alteration of any component causation factors will alter the level of risk).
- does enable assessment of cumulative impacts (e.g. soil loss, productivity, water quality, climate variability, etc.)
- is relatively cost-effective (e.g. erosion risk associated with sheet erosion is primarily a spatial desktop exercise)
- is scientifically credible and statistically robust (i.e. application of the Revised Universal Soil Loss Equation (RUSLE) is widely accepted as a method for calculating sheet erosion risk, despite recognised limitations).

Measuring a change in the level of Erosion Risk provides a useful tool for assessing changes in soil retention (and therefore health), effectiveness of management practices and appropriateness of land use. Furthermore, as well as reducing soil loss, Erosion Risk is also linked to other intermediate outcomes, including improved fertility, increased adoption of best management practices (BMP) and improved water quality (for soil health) and viable rural production (for agricultural land). This is also fundamental to improving reef water quality under the Reef Plan which aims to reduce sediment loads by 20%. Available mapping is located in Appendix A.

Gully Erosion

Gully erosion in the WBB will be monitored by assessing the extent and severity of digitally captured erosion gullies. Erosion extent and severity is influenced by the same natural and artificial / human pressures as Erosion Risk, and requires similar information inputs. Similarly, measuring changes in gully extent and severity provides a useful tool for assessing changes in soil retention (and therefore health), effectiveness of management practices and appropriateness of land use. Furthermore gully extent will affect the availability of land for viable rural production; gully severity / activity will influence the need for increased adoption of Best Management Practices (BMP) and improved fertility; and both extent and severity will have implications for improved water quality.

Measuring gully erosion extent and severity by means of traditional field methods is usually a time and resource intensive exercise, mainly used for a select number of sites. However, application of remote sensing methodologies provides a more efficient and cost-effective way of monitoring the extent and severity of gully erosion across the region. Using imagery to digitise the location of erosion gullies is a straightforward way of capturing extent, while using groundcover as a measure for assessing gully stability provides an effective process for monitoring changes in severity. Available mapping is located in Appendix A.

Conceptual understanding of the pressure and response relationships

Sheet & Stream Bank Erosion

Erosion Risk is directly proportional to soil loss, which is influenced by:

- rainfall – e.g. the greater the frequency, intensity and duration of rain, the greater the risk of erosion).
- erodibility (i.e. the soil's susceptibility to erosion based on inherent soil properties such as texture, structure, organic matter, dispersivity, etc.) – e.g. light textured / sandy, poorly structured dispersive soils with low organic matter are more likely to erode.
- slope length – e.g. the speed of runoff increases with slope length, increasing erosion risk.
- slope percent – e.g. the speed of runoff increases with gradient, increasing erosion risk.
- cover – e.g. the less cover, the greater the risk of erosion.
- management practices – e.g. erosion risk increases with the level of soil disturbance.

Additional influences affecting stream bank Erosion Risk include:

- gully presence – e.g. stream bank erosion risk will be greater in areas where an erosion gully enters the stream
- stream curvature – i.e. flow velocity is greater on the outside of a steam bend, thus increasing the risk of erosion for this area of bank.

The conceptual understanding of how sheet and streambank erosion occurs within the landscape is illustrated below in Table 8. The first row describes the process of how human activities and natural events put pressure on systems causing physical and chemical changes to the environment, which can be measured by assessing indicator condition and trend. Row two describes the assumptions about the scientific understanding of erosion, while row three describes the data necessary to monitor condition and trend.

Table 8 - Tool for identifying sheet and stream bank indicators and information needs

	Pressures		Physical / chemical / attitudinal changes	Indicator Condition & Trend
	Human Activity	Natural Events		
Process / Function of sheet & stream bank erosion	Land use and land management influence the degree of soil disturbance, period of soil exposure and concentration of runoff.	Landscape hydrology - comprising climate (rainfall frequency & intensity), landscape attributes (slope gradient & length of slope), soil properties (susceptibility to erosion) and the level of groundcover – influence landscape pressures and the risk of erosion.	High levels of rainfall frequency and intensity; steep, long slopes; absence of ground cover; high erodibility; lengthy exposure; high levels of disturbance; and runoff concentration all increase the risk of erosion.	Change in level of Erosion Risk.
Assumptions	Land use is related to land management and land management is directly related to the amount of disturbance, period of exposure and concentration of runoff.	Landscape pressures are known. Rainfall, slope and cover influence runoff, which influences the risk of erosion in conjunction with soil erodibility.	High levels of rainfall frequency and intensity; steep, long slopes; absence of ground cover; high erodibility; lengthy exposure; high levels of disturbance; and runoff concentration all increase the risk of erosion	Assessment standards accurately reflect levels of human activity, natural events and landscape and soil attributes. RUSLE, which calculates Soil Loss, accurately reflects the level of Erosion Risk.
Information needs (data)	- Management Practices - Land Use (QLUMP) - Cover (BGI) - Projected Foliage Cover (PFC) - Extension services(soil con advice) - Industry BMPs - Remnant Veg - Disturbance (clearing permit areas) - Soil Con Plans (state govt) - Exposure periods	- Rainfall frequency - Rainfall intensity - Slope % - Slope length - DEM - Cover (BGI) - PFC - Erodibility	- RUSLE factors - Type of concentration (natural / artificial)	Erosion Risk (categories).

Gully Erosion

Gullies are influenced by the soil loss factors (i.e. rainfall, soil erosivity, slope length and gradient, cover and management) within their catchment area. In fact, it could be said that the presence of an erosion gully is a culmination of high levels of these factors, and as such, they can be directly taken into account by mapping gully extent.

All active erosion gullies will continue to grow until they reach a state of equilibrium, when they become inactive. Whether a gully is active (i.e. gully activity) will be determined by how stable the gully is (i.e. gully stability), which in turn is influenced by the same factors as soil loss. However, the level of groundcover will also be influenced by gully stability – i.e. no ground cover will be present within an extremely unstable gully.

As such, gully severity can be determined by gully activity, which can be determined by the presence of groundcover within and immediately surrounding a gully.

The conceptual understanding of how gully erosion occurs within the landscape is illustrated below in Table 9. The first row describes the process of how human activities and natural events put pressure on systems causing physical and chemical changes to the environment, which can be measured by assessing indicator condition and trend. Row two describes the assumptions about the scientific understanding of erosion, while row three describes the data necessary to monitor condition and trend.

Table 9 - Tool for identifying gully erosion extent and severity indicator and information needs

	Pressures		Physical / chemical / attitudinal changes	Indicator Condition & Trend
	Human Activity	Natural Events		
Process/Function of gully erosion	Land use and land management influence the degree of soil disturbance, period of soil exposure and concentration of runoff in a gully catchment.	Landscape hydrology influences landscape pressures and gully extent and severity.	High levels of rainfall frequency and intensity; steep, long slopes; absence of ground cover; high erodibility; lengthy exposure; high levels of disturbance; and runoff concentration all increase gully extent and severity.	Change in gully erosion extent and severity.
Assumptions	Land use is related to land management and land management is directly related to the amount of disturbance, period of exposure and concentration of runoff. Gullies are affected by influences in their catchments.	Landscape pressures are known. Rainfall, slope and cover influence runoff, which, in conjunction with soil erodibility, influence gully erosion extent and severity. These factors influence presence of groundcover, which is proportional to and therefore a good surrogate for gully activity/stability (i.e. severity).	High levels of rainfall frequency and intensity; steep, long slopes; absence of ground cover; high erodibility; lengthy exposure; high levels of disturbance; and runoff concentration all increase gully extent and severity.	Assessment standards accurately reflect levels of human activity, natural events and landscape and soil attributes. Groundcover presence accurately reflects gully activity/stability (i.e. severity).
Information needs (data)	- Management Practices - Land Use (QLUMP) - Cover (BGI) - Projected Foliage Cover (PFC) - Extension services(soil con advice) - Industry BMPs - Remnant Veg - Disturbance (clearing permit areas) - Soil Con Plans (state govt) - Exposure periods	- Rainfall frequency - Rainfall intensity - Slope % - Slope length - DEM - Cover (BGI) - PFC - Gully extent	Gully Severity	Gully Extent & Severity

4.5 Acid Sulfate Soil (ASS)

2020 Target - The extent of acidification caused by the disturbance of Acid Sulfate Soil will not exceed the 2015 baseline.

ASS Disturbance

Acidification refers to any acidity caused by the disturbance of Acid Sulfate Soils which has not been neutralised during/post disturbance.

ASS are soils containing iron sulfides, mainly formed under estuarine conditions in the last 10 000 years. In their natural state, ASS are commonly waterlogged, have neutral pH and are benign. In this state they are called potential acid sulfate soils (PASS). However when exposed to air, the sulfides oxidise to form sulfuric acid, acidifying soil and water, and releasing iron, aluminium and possible heavy metal contaminants. The resulting severely acidified soil can often have pH<4.0, when it is called actual acid sulfate soils (AASS). The acidification of soil, groundwater and surface water caused by disturbance of ASS can reduce farm productivity, degrade infrastructure, have detrimental impacts on terrestrial and aquatic habitats, and harm aquatic organisms.

Measuring the extent (hectares) and severity (pH) of acidified ASS provides an effective tool for assessing changes in ASS status over time. Monitoring will allow identification of areas requiring action, and assessment of mitigation measures. It can also be used to guide planning and aid in direction of future settlement patterns. Available mapping is located in Appendix A.

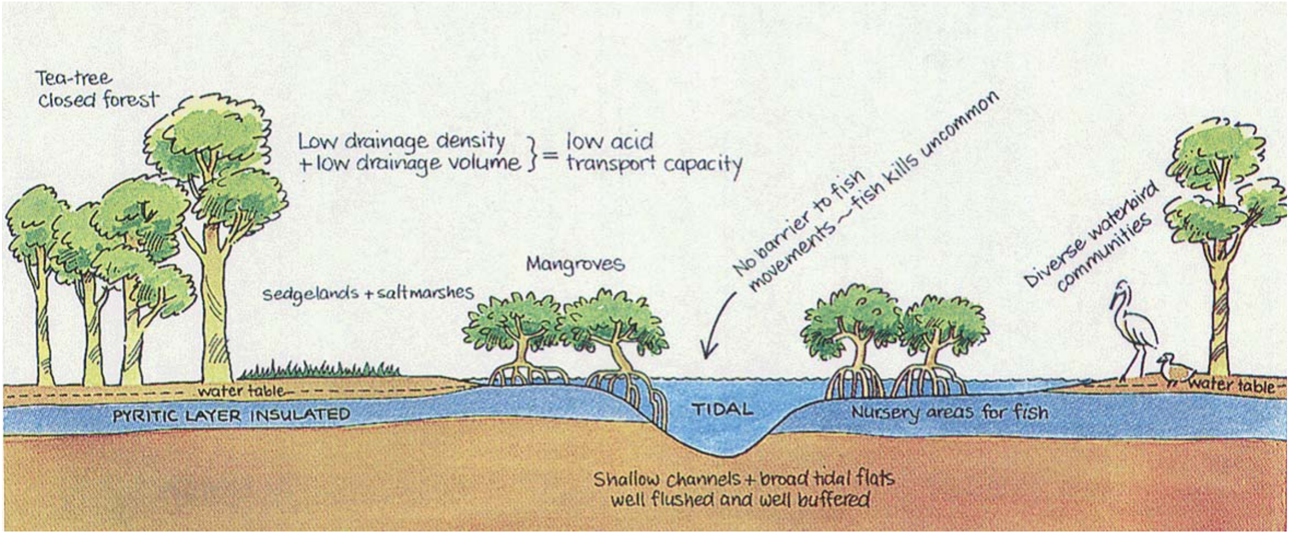
Conceptual understanding of the pressure and response relationships

Much of the Queensland population is located close to the coast, with land close to water in particular demand for development. As a result there are significant pressures on the low lying coastal areas where ASS are present. Activities such as sand extraction can also be located in these areas. Agricultural production from crops such as sugarcane is common in ASS-prone areas, with (historical) drainage works often constructed in an attempt to improve production. These activities usually disturb ASS and groundwater, which can result in acidification of soil, groundwater and surface water.

The natural occurrence of ASS is shown in Figure 3 where acid events from oxidation of ASS are often of low frequency, low magnitude and have short duration (Sammut, J. 2000, An introduction to acid sulfate soils). Significant droughts can result in oxidation of ASS and subsequent acidification; however the impacts are likely to be much less than if disturbed by human activity.

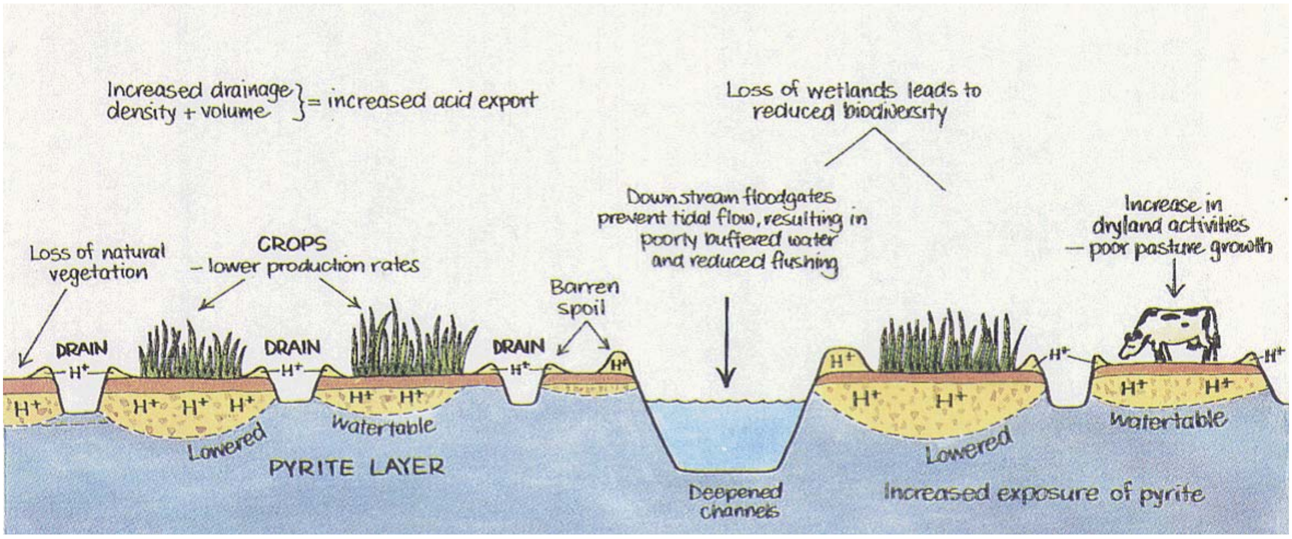
Figure 4 shows ASS in a disturbed environment, where acid events from oxidation of ASS have a high frequency, high magnitude and can persist for a longer duration.

Fig 3- ASS in a natural setting



(Sammut, J. 2000. An introduction to acid sulfate soils)

Fig 4- ASS in a disturbed setting



(Sammut, J. 2000. An introduction to acid sulfate soils)

Avoiding disturbance of ASS is the best management option, as ASS is usually benign if left undisturbed. If disturbed, management strategies aim to limit the amount of sulfides exposed to the air and to neutralise the acid in the soil and water before the acid (and any contaminants) is released to receiving environments. Incorporation of ASS information into the WBB Regional Plan and Local Authority Planning Schemes is an effective tool to identify and implement appropriate development in high risk areas.

The conceptual understanding of how ASS occurs within the landscape is illustrated below in Table 10. The first row describes the process of how human activities and natural events put pressure on systems causing physical and chemical changes to the environment, which can be measured by assessing indicator condition and trend. Row two describes the assumptions about the scientific understanding of Acid Sulfate Soil processes while row three describes the data necessary to monitor condition and trend.

As such, gully severity can be determined by gully activity, which can be determined by the presence of groundcover within and immediately surrounding a gully.

The conceptual understanding of how gully erosion occurs within the landscape is illustrated below in Table 9. The first row describes the process of how human activities and natural events put pressure on systems causing physical and chemical changes to the environment, which can be measured by assessing indicator condition and trend. Row two describes the assumptions about the scientific understanding of erosion, while row three describes the data necessary to monitor condition and trend.

Table 10 - Tool for identifying gully erosion extent and severity indicator and information needs

	Pressures		Physical / chemical / attitudinal changes	Indicator Condition & Trend
	Human Activity	Natural Events		
Process/Function of ASS	Land use and land Management disturbs soil and groundwater, exposing ASS to oxygen	Droughts can result in exposure of ASS to oxygen by lowering groundwater tables.	Exposure of ASS to oxygen results in generation of acid - acidifying soil, groundwater and surface water. Detection of impacts should lead to improved management.	Change in extent and severity of acidification from acid sulfate soils.
Assumptions	Intensive land use/land management will result in more exposure of ASS to oxygen than would occur in a natural setting. Impacts will be Detectable. Negative impacts on human activities may be experienced.	Some exposure of ASS to oxygen will occur in a natural setting, but impacts are likely to be minor in comparison to a disturbed site. Impacts will be Detectable. Ecosystem will have enough resilience to handle natural events	Disturbing ASS will result in negative impacts. It should be possible to identify natural and human induced impacts on ASS. Improved management measures will be undertaken once impacts are identified. Landowners will be willing to implement improved management.	ASS maps will accurately represent the baseline extent and severity of acidification from ASS.
Information needs (data)	- ASS maps - LiDAR elevation data - Remnant vegetation - Land use mapping - Land tenure DCDB (& lot size)	- ASS maps - soils mapping - geology mapping - aerial photography - LiDAR elevation data - contour data - gamma radiometric survey data - Remnant vegetation - BGI (Bare Ground Index) - Land use mapping - Rainfall - Evaporation	- Soil pH	Extent and severity of acidification from acid sulfate soils.

4.6 Cropping Land

2020 Target – Extent of suitable Cropping Land (i.e. cropping, horticulture and plantation forestry) is maintained at the 2015 baseline.

Retained Cropping Land

Note: 'Cropping Land' includes both cropped and undeveloped land suitable for crop production

Cropping Land is recognised as a finite and national resource that must be conserved and managed for the benefit of future generations. This resource includes land which is capable of sustainable use for agriculture, with a reasonable level of inputs and without causing degradation of land or other natural resources. Queensland's best Cropping Land supports economic growth for regional communities, is a scarce resource, and is subject to competition from urban and mining interests. Cropping Land must be protected from permanent alienation.

Measuring the extent in hectares of suitable Cropping Land and areas lost to permanent alienation provides an effective tool for assessing changes in retained Cropping Land status over time. It can also be used to guide planning and aid the direction of future settlement patterns. Available mapping is located in Appendix A.

Conceptual understanding of the pressure and response relationships

The productive capacity of Cropping Land can be impacted by competition between resultant changes in land use, fragmentation of the resource base, and from conflict due to incompatible adjacent land uses.

Globally, food security, scarcity of suitable Cropping Land and the intensifying demand for food, fibre and energy products from a growing population is putting pressure on Cropping Land. On a local scale, demand for land is increasing to cater for strong population growth, particularly in regional areas. Carbon sequestration forest agreements and nature conservation covenants are usually long term, restricting agricultural production, but are deemed to not alienate the resource from agricultural production given the land can be cleared if required. Energy related industries require access to specific natural resources (such as coal, gas, soil or water) and access to infrastructure. Due to the nature of these activities (e.g. open cut mining), these industries permanently impact on the availability and productive capacity of the land.

Urban encroachment onto suitable Cropping Land permanently alienates the resource, and is often associated with diminished productivity due to conflict that is associated with incompatible adjacent land uses (e.g. spray drift and noise impacting on residential areas). These impacts are often cumulative when the resource has been fragmented due to scattered residences locating within traditional farming areas. Agricultural cropping requires having access to fertile soils, water, transportation and communication infrastructure, service centres and markets. Those areas which meet these criteria are scarce.

The pressure on Cropping Land extent is associated with the level of competition from urban, forestry, nature conservation and energy development, and is extreme. Agricultural industries that rely on processing and infrastructure (such as sugar mills, rail and irrigation infrastructure) are also at risk, due to the cumulative impacts of loss of the Cropping Land to support the industry. This supporting infrastructure needs to be maintained. The social and economic contributions of the agricultural sector to regional areas are significant and Cropping Land needs to be sufficiently protected against permanent alienation and diminished productivity.

A conceptual understanding of the pressures on Cropping Land extent is provided in Table 11. The first row describes the human activities and natural events that put pressure on the resource base, causing changes to the area of retained Cropping Land. Row two describes the assumptions about the scientific understanding of the pressures on Cropping Land, while row three describes the data necessary to monitor condition and trend.

Table 11 - Tool for identifying indicator and information needs

	Pressures		Physical / chemical / attitudinal changes	Indicator Condition & Trend
	Human Activity	Natural Events		
Process/Function of GQAL	Demand for Cropping Land for urban expansion. Demand for Cropping Land for mining and energy resources. Revenue generated from urban development, forestry and mining.	Climate change. Resource loss due to extreme weather – cyclones, flooding and drought	Changes in Cropping Land due to alienation. Changes in Cropping Land due to diminished productivity from natural events.	Extent of retained Cropping Land. Measurable changes in extent of retained Cropping Land due to alienation Measurable changes in extent of retained Cropping Land over time due to diminished productivity
Assumptions	Suitable alternative sites will be available to accommodate urban and mining sector expansion. Competition between Cropping Land, mining, carbon sequestration forestry, nature conservation and urban development will continue to put pressure on the resource base.	Minor areas of Cropping Land will be lost due to natural events.	The economic and social benefits of maintaining a strong agricultural base in the region are significant. The infrastructure requirements for maintaining a strong agricultural base will be maintained.	Planning processes are able to accurately reflect commitment to protect Cropping Land from alienation and diminished productivity. Preferred settlement patterns are able to be directed away from areas with a strong agricultural base.
Information needs (data)	- GQAL or ALC mapping (Class A & B) - land use mapping - planning scheme maps & urban footprint - area covered by mines, quarries and petroleum products - Cadastral mapping - Satellite imagery (orthophotos and aerial photos) - Population trends	Flooding Sea level rise	Depth and salinity of groundwater.	Extent of retained Cropping Land

4.7 Grazing Land

2020 Target - Ground cover of Grazing Land is maintained at the 2015 baseline

Grazing Land

Land Condition within grazing systems is commonly assessed based on the Land Condition Framework (as promoted by the Grazing Land Management strategy) which takes into account factors such as surface cover (i.e. plant material including litter, scalded/bare areas, erosion, salinity), weeds, abundance of desirable grass species (i.e. perennial, productive and palatable) and woody thickening. Land condition is important to maintain economic productivity and soil health. Percent surface cover is a convenient tool to monitor grazing land health for each of the Soil Management Units as it is monitored regularly throughout Queensland by the State Government. Each Soil Management Unit has inherent chemical (e.g. nutrient levels) and physical properties (e.g. plant available water capacity) resulting in a certain range of surface cover as infl uenced by local seasonal variation (e.g. rainfall). Due to seasonal fluctuations and rainfall variability over the Burnett Mary Region, comparison of pasture health at any one time is based on comparison with long term averages. Any decrease in surface over in the medium term can be attributed to land management. Climate variability will influence pasture cover in the long term.

Grazing land supports economic growth for regional communities, is a finite resource and is subject to competition from primary industries such as Mining and Forestry. Loss of pasture cover to land degradation (erosion, salinity) can also be monitored. Measuring pasture condition (surface cover) can only occur in areas with a tree foliage cover of <20%. Available mapping is located in Appendix A.

Conceptual understanding of the pressure and response relationships

Management actions will aim to maintain or improve the level of surface cover in our soils through improved grazing land management and improved soil health. Management that supports the target includes good grazing management, maintenance of soil fertility (chemical and physical), low temperature burning at appropriate times, rehabilitation of degraded areas and reduced land degradation such as salinity, erosion and soil contamination. The effect of each of these factors is individual to each different soil type considered.

The conceptual understanding of how surface cover changes in the landscape is illustrated below in Table 12. The first row describes the process of how human activities and natural events put pressure on systems causing physical and chemical changes to the environment, which can be measured by assessing indicator condition and trend. Row two describes the assumptions about the scientific understanding of pressures and response to ground cover while row three describes the data necessary to monitor condition and trend.

Table 12 - Tool for identifying Grazing Land condition indicator and information needs

	Pressures		Physical / chemical / attitudinal changes	Indicator Condition & Trend
	Human Activity	Natural Events		
Process/Function of secondary salinity	Land use and land management influence the amount of pasture growth and retention.	Climate, soil type, vegetation cover and pasture type influence the amount of surface cover.	Reduced surface cover result in reduced productivity, and soil health declines related to structure, moisture holding capacity, nutrient availability and erosion resistance.	Changes in percentage of surface cover.
Assumptions	Land management is directly related to the amount of surface cover in all landscapes.	The amount of pasture growth is related to climate (rainfall, evaporation and temperature), topography, soil type (texture, pH, fertility & parent material) and how they interact with land management techniques.	Surface cover levels behave in a uniform manner where all soil, topographic and climate variables are equal.	Surface cover changes accurately reflect changes in land management practices over time.
Information needs (data)	- Land use statistics or mapping - History of farming or land clearing - Current vegetation mapping - BGI (Bare Ground Index)	- Climate data (temperature, rainfall, evaporation) - Vegetation coverage and type. - Soil type (parent material, soil depth etc.) - Topography (elevation, slope, rockiness) - Land use. - Geology	Measured levels of surface cover across all soils	Extent and variability of surface cover levels under a range of common land management practices.

5.0 Future Investment

We need to take action to reduce risks and threats and improve biophysical condition. However, we also need to improve policy and planning, awareness and behaviour, adoption of improved management practices and to improve the region's understanding and knowledge of natural systems and the interaction of human activities with those systems. All of these activities have one thing in common, which is the need for investment of resources - both people and funding.

The specific activities identified for the delivery of Desired Outcomes for Land and Soil Resource indicators, as identified through community consultation and scientific expert panels, are listed in Table 13. The activities were identified for addressing key issues for the Land and Soil Resource indicators and were subject to a prioritisation process examining:

- cost
- benefit
- risk
- barriers to adoption
- social acceptability
- Carbon sequestration potential
- maladaptation.

Each target describes activities to achieve the desired outcomes. Each of the activities for Planning and Governance (which includes industry), On-Ground, Community Capacity Building and Science are ranked from 1 to 3 (1 high, 2 moderate, 3 low). An overall ranking (HIGH, MODERATE, LOW) is applied to each Target for prioritisation purposes.

Table 13 - Activities identified for the delivery of Land and Soil Resource Desired Outcomes.

2020 Targets	Activity Category	Activity	Priority Ranking	Carbon Sequestration / Mitigation Co-Benefit
Salinity extent and severity is maintained at 2015 baselines. MODERATE	Planning & Governance	Incorporate baseline data into (town) planning decisions to avoid inappropriate development.	1	
	On-Ground	Improve ground cover / vegetation and crop and irrigation management. Ensure infrastructure does not exacerbate salinity problems (e.g. channel / dam leakage).	2	Increased vegetative ground cover will result in increased carbon sequestration in both plants and soil, as well as reduced soil erosion. (Increased veg cover ⊠C seq. Reducing salinity reduces erosion)
	Community Capacity Building	Ongoing education re salinity processes and management option. Provide / maintain extension services.	1	
	Science	Complete baseline data – salinity extent and severity. Implement Monitoring & Evaluation program.	1	
Soil acidification is maintained at 2012 baseline. LOW	Planning & Governance	Incorporate baseline data into development of BMP for all crop production.	2	
	On-Ground	Implement BMP.	1	Healthy cropping land soils retain greater levels of soil carbon than degraded soils. (Maintain soil health to maintain soil carbon in cropping land.)
	Community Capacity Building	Ongoing education re soil acidification processes and management options. Provide / maintain extension services.	2	
	Science	Implement Monitoring & Evaluation program.	3	

2020 Targets	Activity Category	Activity	Priority Ranking	Carbon Sequestration / Mitigation Co-Benefit
Soil Organic Matter is maintained at the 2012 baseline for agricultural land.	Planning & Governance	Incorporate baseline data into development of BMP for all crop production.	2	
	On-Ground	Implement BMP.	1	Healthy cropping land soils retain greater levels of soil carbon than degraded soils. (Maintain soil health to maintain soil carbon in cropping land.)
	Community Capacity Building	Ongoing education re the benefits of retaining/ building SOM and management options.	2	
	Science	CImplement Monitoring & Evaluation program.	3	
Sheet erosion risk, stream bank erosion risk and gully erosion extent and severity do not exceed 2015 baseline levels. HIGH	Planning & Governance	Incorporate baseline data into development of BMP for all land use.	3	
	On-Ground	Implement BMP	1	Retained soils retain stored carbon in the landscape. (Maintaining soil carbon levels.)
	Community Capacity Building	Ongoing education re soil erosion processes and management options. Provide / maintain extension services.	1	
	Science	Accumulate existing information into relevant format. Implement Monitoring & Evaluation program.	2	
The extent of acidification caused by the disturbance of ASS does not exceed the 2015 baseline. LOW	Planning & Governance	Incorporate baseline data into (town) planning decisions to avoid inappropriate development.	1	
	On-Ground	Avoid development or implement BMP. Ensure infrastructure does not exacerbate ASS problems (e.g. channel / dam construction). Manage groundwater to avoid exposing potential ASS.	2	Areas of ASS inherently retain high levels of soil carbon, avoiding their disturbance ensures retention of that carbon. (By avoiding development on ASS area soil carbon is maintained / improved.)
	Community Capacity Building	Ongoing education re ASS processes and management option. Provide / maintain extension services.	2	
	Science	Complete baseline data – ASS disturbance extent. Implement Monitoring & Evaluation program.	3	
The extent of Cropping Land (i.e. cropping, horticulture and plantation forestry) is maintained at 2015 baseline. HIGH	Planning & Governance	Incorporate baseline data into (town) planning decisions to avoid inappropriate development.		
	On-Ground	Avoid inappropriate development		The capacity of cropping land to retain soil carbon is maintained if such areas are not subject to urban and industrial development. (By avoiding development on cropping land soil carbon is maintained / improved.)
	Community Capacity Building			
	Science	Complete baseline mapping. Implement and M&E		
Groundcover of Grazing Lands is maintained at the 2015 baseline. HIGH	Planning & Governance	Incorporate baseline data into development of BMP for all land use.		
	On-Ground	Implement BMP and appropriate fire management		Increased vegetative ground cover levels in grazing lands result in increased carbon storage. (Maintain / improve soil carbon through groundcover retention.)
	Community Capacity Building	Ongoing education re BMP and management options. Provide / maintain extension services		
	Science	Implement Monitoring & Evaluation program.		

The activities to maintain **salinity** extent and severity at the 2015 baseline aim to improve land management activities such as lower ground water levels through improved plant growth (crops, pastures and trees), improved irrigation methods (water application, water quality and water table monitoring), soil and land management, and engineering solutions (e.g. drainage, resistant infrastructure). Other activities include improved planning decisions by avoiding development on saline areas or if development cannot be avoided, allow governments and industry to implement relevant codes to minimise damage to infrastructure and assets. In many cases, the knowledge of the landscape processes that drive salinity are well recognised by the science community, but public knowledge is poor. Therefore, community education and supply of extension services needs to be improved.

Soil acidification is a slow process mainly associated with plant product removal from a site and fertiliser use on acid sandy to loamy textured cropping soils. Management aims to implement best management practices such reducing fertiliser applications, liming and retaining crop residues. Other activities include the development of BMPs by industry and community education.

Soil loss through **erosion** has significant environmental, economic and social implications which often cannot be reversed. For example, loss of topsoil inhibits crop and plant growth, interferes with farming operations and may damage infrastructure, while sediment-laden runoff and sediment deposition negatively impact on terrestrial and aquatic ecosystems, with repercussions throughout the agricultural, fisheries, tourism and conservation sectors. The various activities are a HIGH priority with the aim to reduce erosion through improved land management through community education and technical support to all land managers. All activities will support Reef Plan through the 20% reduction in sediment and nutrient loads to the reef waters.

The acidification of soil, groundwater and surface caused by **disturbance of ASS** can reduce farm productivity, degrade infrastructure, have detrimental impacts on terrestrial and aquatic habitats, and harm aquatic organisms. As the disturbance of ASS is regulated by existing government planning provisions, the overall target is a low priority. The activities aim to either avoid disturbance or if disturbed, manage the acidification to avoid damage to the environment, infrastructure and assets.

Good quality agricultural land (GQAL) – **Cropping Land** - is recognised as a finite and national resource that must be conserved and managed for the benefit of future generations. The productive capacity of agricultural land can be impacted on by competition between and resultant changes in land use, fragmentation of the resource base, and from conflict due to incompatible adjacent land uses. The activities aim to improve planning decisions to reduce urban encroachment onto agricultural land, as any alienation permanently alienates the resource, and is often associated with diminished productivity due to conflict that is associated with incompatible adjacent land uses (e.g. spray drift and noise impacting on residential areas).

Grazing Land supports economic growth for regional communities. Management actions will aim to maintain or improve the level of surface cover in our soils through improved grazing land management and improved soil health (as described above). Best management practices which support the target includes good grazing management, maintenance of soil fertility (chemical and physical), low temperature burning at appropriate times, rehabilitation of degraded areas and reduced land degradation such as salinity, erosion and soil contamination. The effect of each of these factors is individual to each different soil type considered. On-going community education and technical support is a high priority.

6.0 Monitoring & Evaluation of the Land and Soil Resource indicators

The NRM and Climate Adaptation Plan 2015 provides an opportunity to coordinate the region's effort towards monitoring the state of the environment and the health and condition of our natural resources. We need both monitoring systems and an evaluation process to get a true picture of how we are tracking.

Monitoring systems are about 'measurements' and aim to tell us something about the state or condition of an asset. Monitoring is generally about data collection, analysis and interpretation and uses indicators that tell us something about the important asset. The indicators are a particular aspect of an environmental asset we can measure over time. When we combine these measurements with a good understanding of how an environmental systems works we are able to assess the condition and identify any trends associated with an asset.

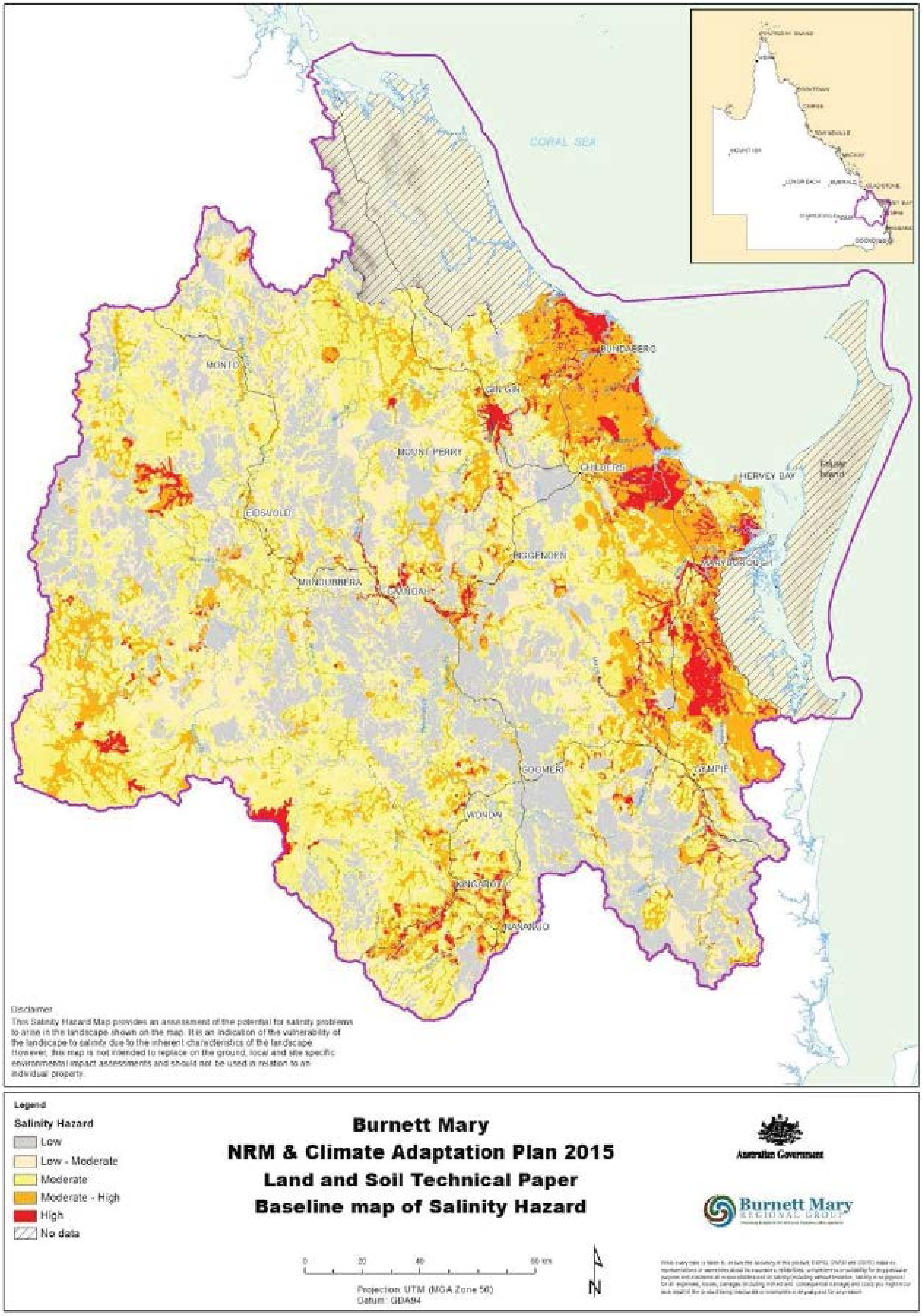
Evaluation tells us about the effectiveness of what we have been doing and if we have achieved the results and outcomes we are looking for from our activities. Evaluation is based on having a good understanding of the 'cause and effect' relationship between the actions we undertake and the variety of outcomes and changes we hope to see along the way to achieving our targets.

For further information about proposed Monitoring and Evaluation Strategies for the Land and Soil Resource, please contact BMRG.

Appendix A

Map	Title	Data Source	Availability
Map 1	Salinity Hazard 2003 baseline	DNRM	Published
Map 2	Soil Acidification Risk 2012 baseline for agricultural land	DNRM	Late 2015
Map 3a	Risk of Soil Organic Matter Decline 2012 baseline for agricultural land	DNRM	Late 2015
Map 3b	Soil Organic Carbon stocks and their uncertainty average 2010 baseline	CSIRO	Published
Map 4	Sheet Erosion Risk 2007 baseline	ENRAS	Published
Map 5	Streambank erosion risk 2015 baseline	BMRG	Published
Map 6	Gully erosion extent and severity baseline (date)	DNRM	N/A
Map 7	Extent of land <5m AHD and comprised of unconsolidated sediment (i.e. areas where Acid Sulfate Soil may occur)	DNRM	Published
Map 8	Agricultural Land Class mapping (2012)	QG	Published
Map 9	Long term mean bare ground for 30 m pixels (Spring 1986 - 2013)	DSITI	Published

Map 1 - Salinity Hazard Potential for Salt Mobilisation 2003 Baseline



Dataset Source: DNRM_SalinityHazardWBB_2003

Map 2 - Soil Acidification Risk 2012 Baseline for agricultural land

Map pending – spatial data currently subject to peer review prior to release.

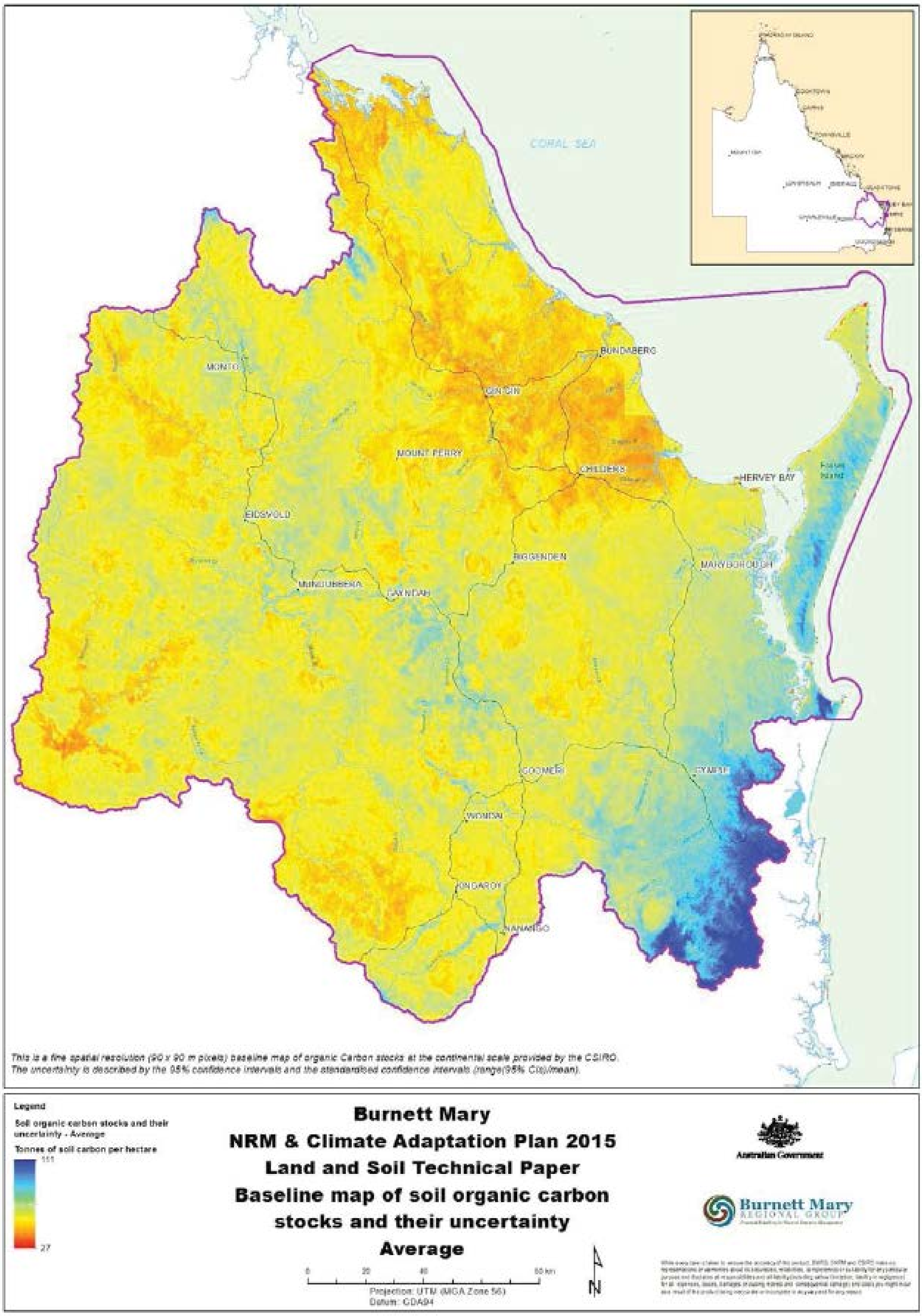
Dataset Source: DNRM_ASOMproject_SoilAcidificationRisk_2012

Map 3a - Risk of Soil Organic Matter Decline 2012 Baseline for agricultural land

Map pending – spatial data currently subject to peer review prior to release.

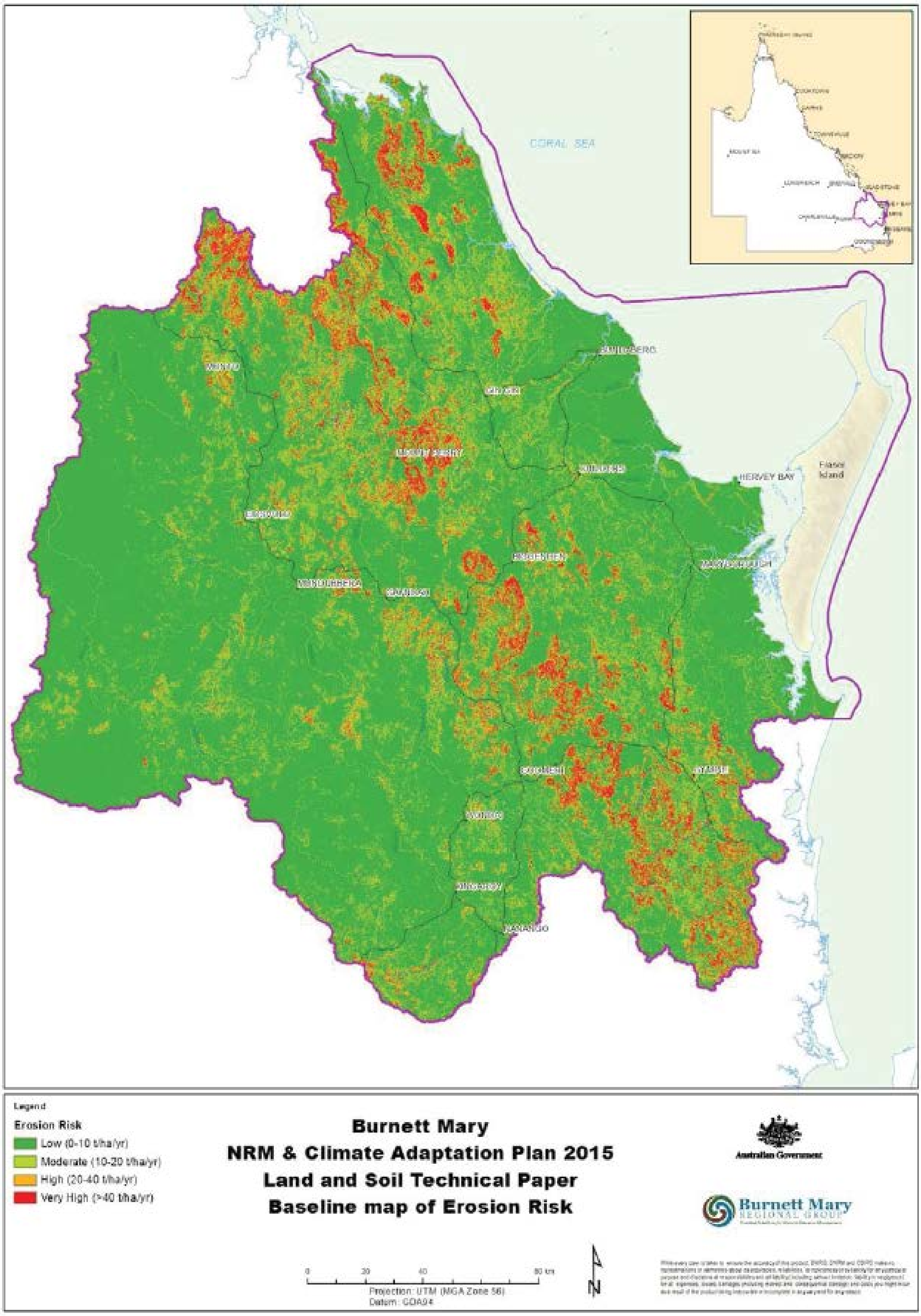
Data Source: DNRM_ASOMproject_SOM-DeclineRisk_2012

Map 3b - Soil organic carbon stocks and their uncertainty average 2010 Baseline



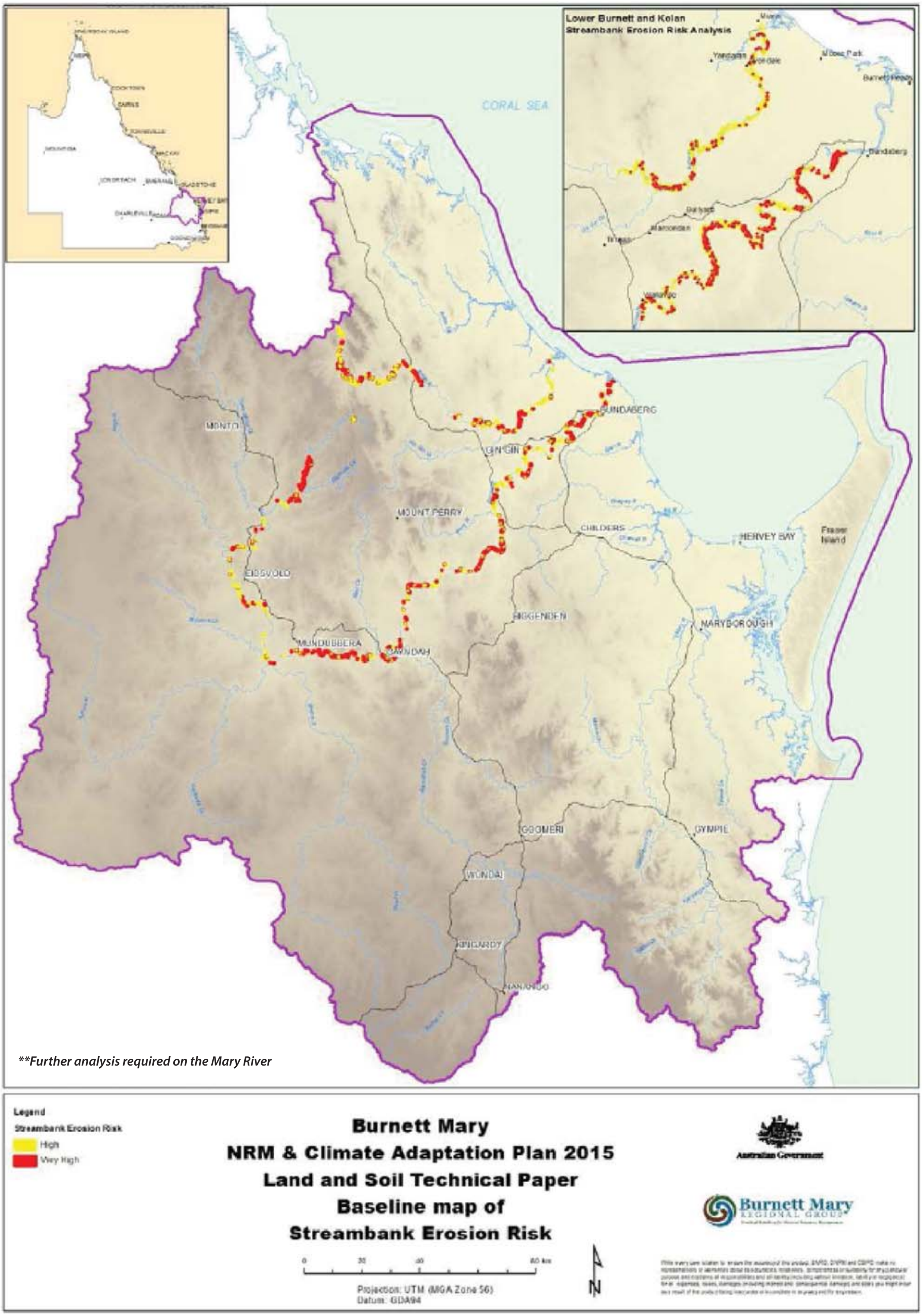
Data Source: CSIRO_SOC-Stocks_2010

Map 4 - Sheet Erosion Risk 2007 Baseline (based on 20 years of data)



Data Source: ENRAS_SheetErosionRisk_2007 (Developed for the WBB ENRAS project, 2007)

Map 5 - Streambank Erosion Risk 2015 Baseline



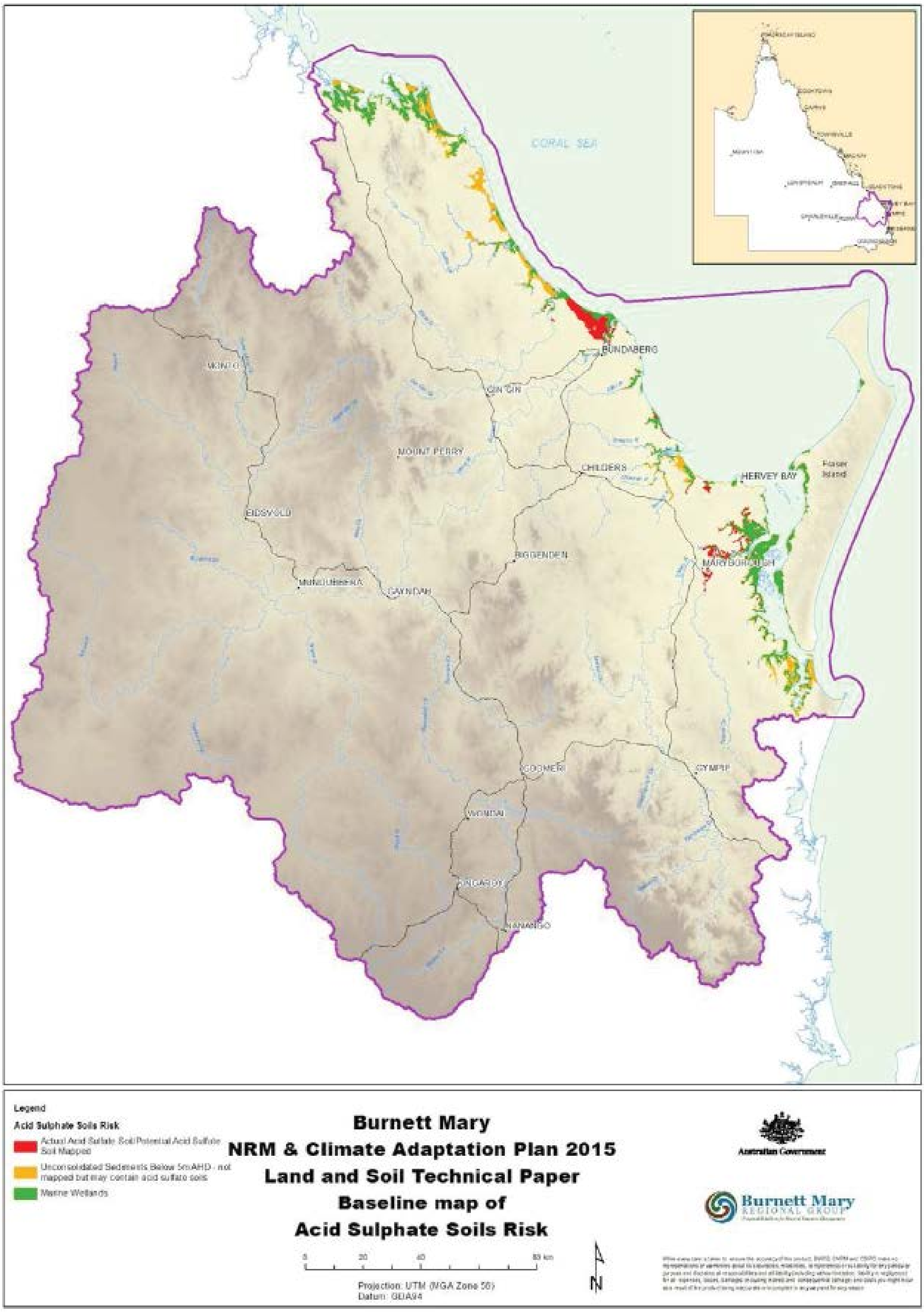
Data Source: BMRG_StreambankErosionRisk_2015

Map 6 - Gully erosion extent and severity

Map is not currently available; maps to be prepared for all Reef catchments. Mapping data for the Mary catchment currently compiled but awaiting validation at sub-catchment scale prior to release. Burnett catchment mapping scheduled for 2016.

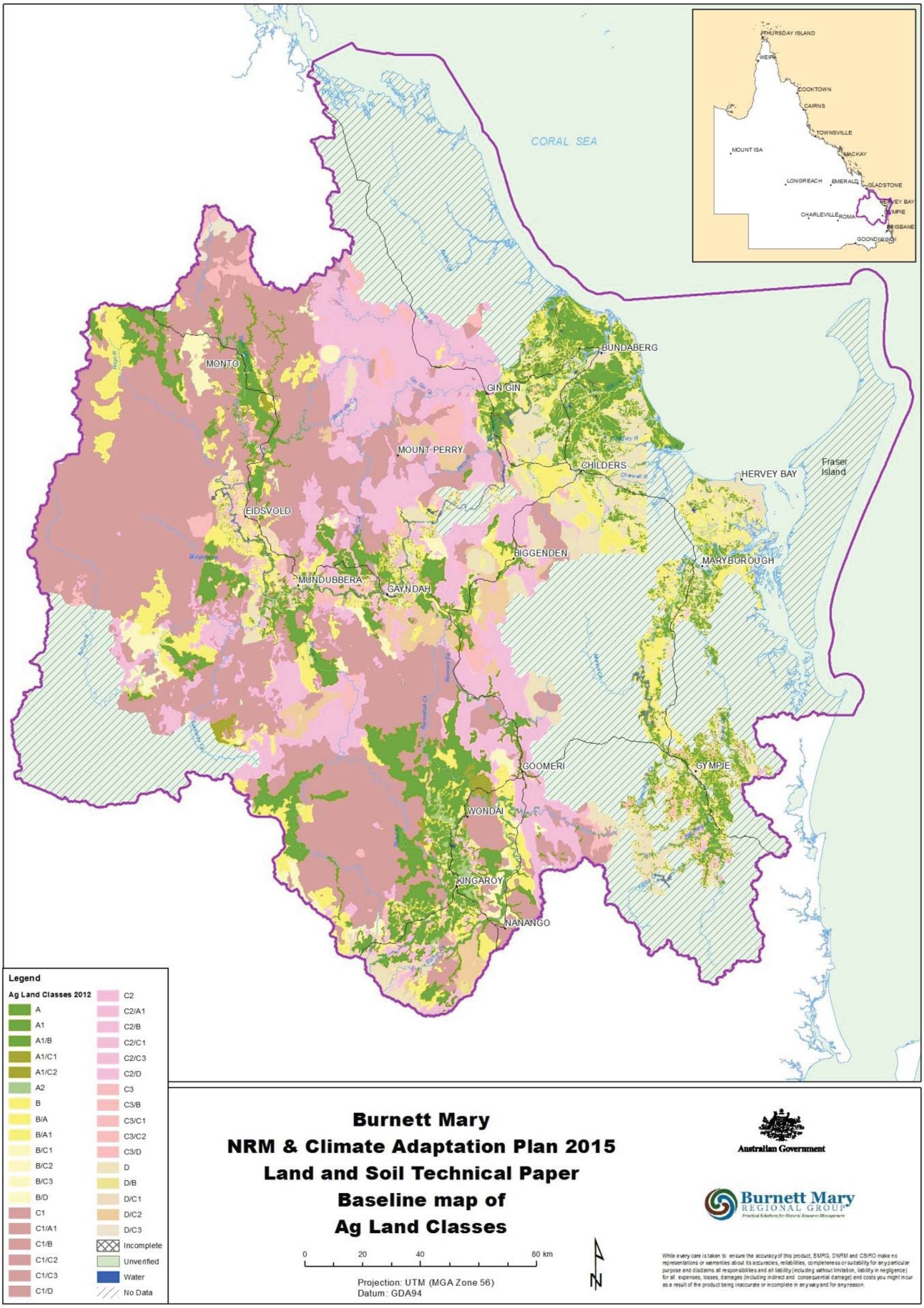
Data Source: DNRM_GullyErosionMappingProject_Date

Map 7 - Extent of land <5m AHD and comprised of unconsolidated sediment. (i.e. areas where Acid Sulfate Soil may occur)



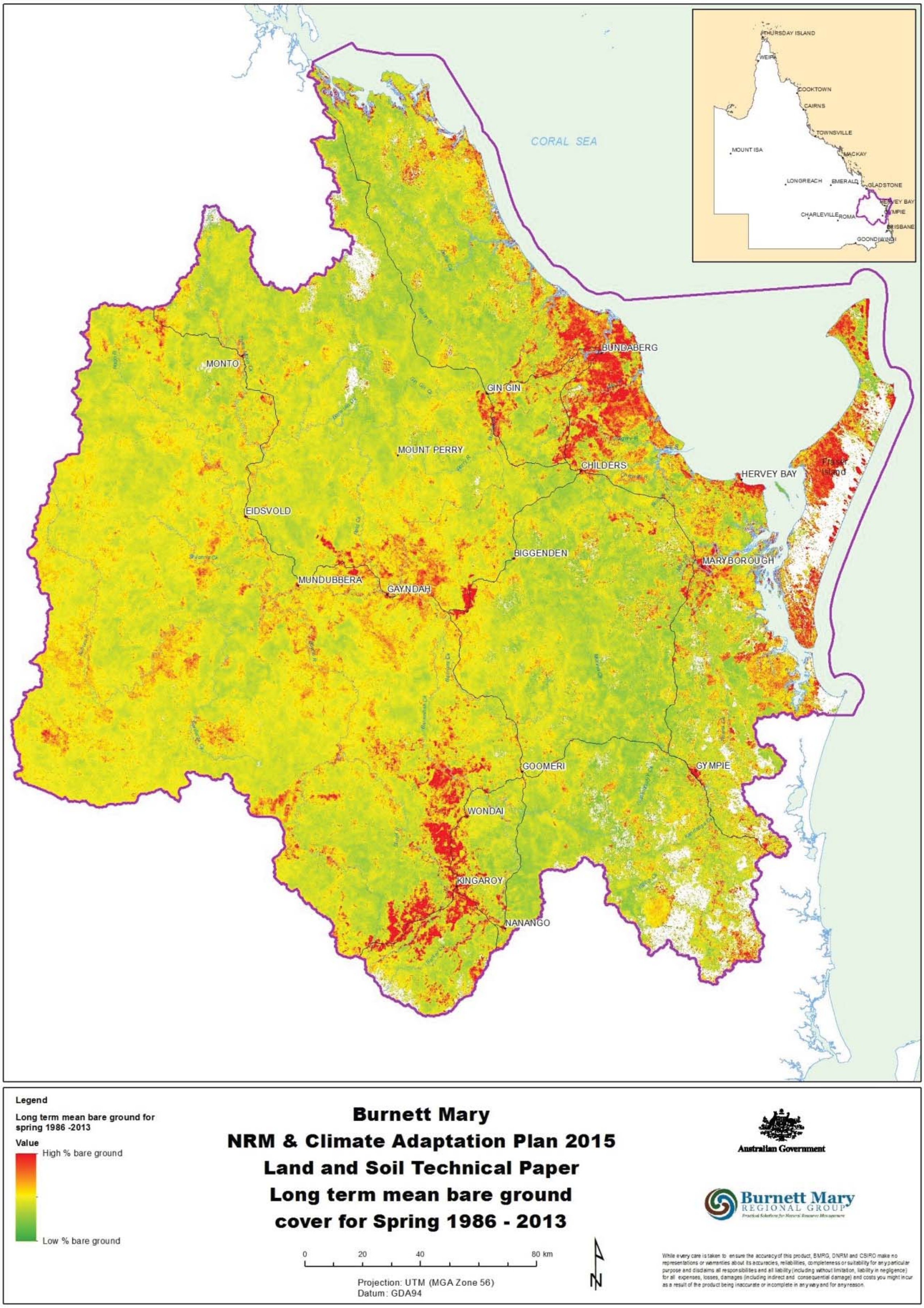
Data Source: DNRM_ASS-Risk_2008

Map 8 - Agricultural Land Class mapping (2012)



Data Source: QldGovt_ALC_2012

Map 9 - Long term mean bare ground for 30m pixels (Spring, 1986 – 2013)



Data Source: DSITI_BGI-SpringAverage_86-13